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Marine Mammal Protection Act and Endangered Species Act Implementation Program 1996

Edited by:
P. Scott Hill
Douglas P. DeMaster

Annual Reports of research carried out on the population biology of marine mammals by the National Marine Mammal Laboratory to meet the 1994 amendments to the Marine Mammal Protection Act and the Endangered Species Act

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Office of Protected Resources
National Marine Fisheries Service
1335 East-West Highway
Silver Spring, MD 20910

National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Alaska Fisheries Science Center
National Marine Mammal Laboratory
7600 Sand Point Way Northeast
Seattle, WA 98115-0070

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Preface

Beginning in 1991, the National Marine Mammal Laboratory (NMML) has been partially funded by the National Marine Fisheries Service's (NMFS) Office of Protected Resources to determine the abundance of selected species in U.S. waters of the eastern North Pacific Ocean. On April 30, 1994, Public Law 103-238 was enacted allowing significant changes to provisions within the Marine Mammal Protection Act (MMPA). Interactions between marine mammals and commercial fisheries are addressed under three new Sections. This new regime replaced the interim exemption that had regulated fisheries-related incidental takes since 1988. The 1994 MMPA amendments continue NMFS's authorization to carry out population studies to determine the abundance, distribution and stock identification of marine mammal species that might be impacted by human-related or natural causes.

The following report, containing 18 papers, is the compilation of studies carried out with fiscal year 1996 (FY96) funding as part of the NMFS MMPA/ESA Implementation Program. The report contains information regarding studies conducted on beluga whales, California sea lions, Dall's porpoise, gray whales, harbor porpoise, harbor seals, humpback whales, ice-associated seals, northern fur seals, and Steller sea lions. Results of gray whale studies from the 1996/97 southbound migration are included in this annual report, although they were conducted with FY97 funding.

This report does not constitute a publication. Further, most of the papers included in this report may be published elsewhere. Any question concerning the material contained within this document should be directed to the authors, or ourselves. Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

P. Scott Hill
Douglas P. DeMaster

MMPA/ESA Implementation Program
Report for 1996

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AERIAL SURVEYS OF BELUGA WHALES IN COOK INLET, ALASKA, JUNE 1996

David J. Rugh[1], Kim E. W. Shelden[1], Janice M. Waite[1], Roderick C. Hobbs[1], and Barbara Mahoney[2]

[1] National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington, 98115

[2] Alaska Regional Office, NMFS, NOAA
222 W 7th Ave., Box 43
Anchorage, Alaska, 99513

Abstract

The National Marine Mammal Laboratory (NMML), in cooperation with the NMFS Alaska Regional Office, the Alaska Beluga Whale Committee (ABWC), and the Cook Inlet Marine Mammal Council (CIMMC), conducted an aerial survey of the beluga whale (*Delphinapterus leucas*) population in Cook Inlet, Alaska, during 11-17 June 1996. This provided a thorough coverage of the coasts around the entire inlet (1,388 km), as well as 1,538 km of offshore transects. Therefore, 100% of the coastal areas where belugas were expected to be during this season were searched one or more times, and 29% of the entire inlet was searched. The 40 hr survey was flown in a twin-engine, high-wing Aero Commander at 244 m (800 ft) altitude and 185 km/hr (100 kt). Throughout this survey, a test of sighting rates was conducted with multiple independent observers on the coastal (left) side of the plane, where most sightings occur. A single observer and a computer operator/data recorder were on the right side. After finding beluga groups, a series of aerial passes were made to allow at least two pairs of observers to make four or more counts of whales. Each pass was also videotaped for later analysis. The sum of the aerial estimates (using median counts from each site, not corrected for missed whales) ranged from 154 to 361 whales, depending on survey day. Estimates of group size ranged from 1 to nearly 300. Half (49%) of the initial sightings occurred more than 1.4 km from the aircraft - the perimeter of the standard viewing area. Of 40 groups recorded in 1994-96, 17 were reported by only one primary observer and missed by the other, while 23 groups were reported by both observers. Most (81%) of the beluga whales seen in Cook Inlet were in the upper Inlet near the mouth of the Susitna River, which is typical of their summer distribution.

Introduction

Beluga whales (*Delphinapterus leucas*) are distributed around most of Alaska from Yakutat to the Alaska/Yukon border (Hazard 1988). This species occurs in five apparent stocks around Alaska: Cook Inlet, Bristol Bay, Eastern Bering Sea, Eastern Chukchi Sea, and the Beaufort Sea (Hill et al. 1997). The most isolated of these is the Cook Inlet stock, separated from the others by the Alaska Peninsula. Beluga whales in Cook Inlet are very concentrated in a few river mouths during parts of the year (as reviewed in Shelden 1994). The geographic and genetic isolation of the whales in Cook Inlet, in combination with their tendency towards site fidelity, makes this stock vulnerable to impacts from large or persistent harvest takes.

Aerial surveys are the established method used to collect distribution and abundance data for beluga whales in Cook Inlet (Klinkhart 1966; Calkins 1984; Calkins et al. 1975; Murray and Fay 1979; Withrow et al. 1994; Rugh et al. 1995, 1996). Traditionally, visual counts or estimates have been used to enumerate groups seen from the air, but they lack repeatability and have no direct measure of accuracy except through tests of independent, paired observers. However, prior to Rugh et al. (1995), there have been no documented tests of dual counting of beluga whales where two observers with nearly identical aerial views made independent searches and counts of whale groups. Barlow (1987, 1993), Øien (1990), Butterworth and Borchers (1988) and others have had independent observers search for cetaceans from ships. Rugh et al. (1990, 1993) conducted shore-based double counts of gray whales. Crete et al. (1991) made double counts from aircraft in surveys for polar bears, but paired observers did not have identical viewing areas. Forney and Barlow (1993) used a partially independent observer design for aerial surveys of cetaceans in which a second observer called out sightings only if they were missed by the primary observer, but the paired observers did not have identical viewing areas. We chose a survey design close to that recommended by Hiby and Hammond (1989) in which paired, independent observers have nearly identical search areas, and their counts are not compared until the research project is complete. Although we did break from the trackline each time a group of beluga whales was reported, it was only after the group was well behind the wing line.

Objectives

The objectives of the aerial surveys were to: 1) make a complete search for beluga whales around the perimeter of Cook Inlet, 2) conduct systematic transects through the center of Cook Inlet, and 3) circle groups of belugas for aerial estimations of group sizes and video documentation. Aerial survey procedures were kept similar to those used in previous studies (e.g., Rugh et al. 1995, 1996). Emphasis was placed on having independent searches and counts of belugas made by at least two observers on the same (nearshore) side of the aircraft. Tests of paired video cameras were run to improve post-season counts of whales (Waite and Hobbs 1995). Summary counts from the aerial effort, in combination with correction factors established through tests such as the paired observer effort, video documentation, and surface timings based on tagged whales will be combined in a separate manuscript to calculate the total number of beluga whales in Cook Inlet.

Methods

Survey Aircraft

The survey aircraft, an Aero Commander 680 FL (N7UP), has twin-engines, high-wings, 10-hr flying capability, and a five-passenger plus one pilot seating capacity. This aircraft has been enhanced for low-speed performance and increased range. There are bubble windows at each of the three primary observer positions, maximizing the search area. An intercom system allowed communication among the observers, data recorder, and pilot. A selective listening control device was used to aurally isolate the observer positions. Positional data were collected from the aircraft's Global Positioning System (GPS) interfaced with a laptop 386 computer used to enter sighting data.

Aerial Records

General descriptions of the aerial operations (startup and shutdown times, names of participants, survey accomplishments, etc.) were kept in a master log maintained by the aerial project principal investigator or delegate. All other data and comment records were entered into the onboard computer. These data entries included routine updates of locations (via the aircraft GPS), percent cloud cover, sea state (Beaufort scale), glare (on the left and right), and visibility (on the left and right). Each start and stop of a transect leg was reported to the recorder. Observer seating positions were recorded each time they were changed, generally every 1-2 hrs to minimize fatigue.

Tides

Because of the broad geographical range of these surveys, and because tide heights in Cook Inlet are highly variable from place to place, our aerial surveys were not synchronized with the predicted low tide with the exception of five surveys that were timed to occur within 1 hour of low tide at the Susitna delta, and one survey that occurred there at high tide (Table 1). This effort to synchronize the counts of whales with low tide was based on the premise that the whales concentrated in narrow channels, making them easier to count than when they spread out at the higher tides. We also took advantage of lower tides in Knik and Turnagain Arms to reduce the effective survey area (at low tide, large areas of mudflats are exposed that would otherwise have to be surveyed), but the timing with the tidal cycle was more opportunistic here than was our timing at the Susitna delta.

Aerial Tracklines

Coastal surveys were conducted on a trackline approximately 1.4 km offshore. The objective was to find beluga whales in shallow, nearshore waters where they typically have been seen in summer (Calkins 1984). The trackline distance from shore was monitored with an inclinometer such that the waterline was generally 10° below the horizon while the aircraft was at the standard altitude of 244 m (800 ft). Ground speed was approximately 185 km/hr (100 knots). This coastal survey included searches up rivers until the water appeared to be less than 1 m deep, based on the appearance of rapids and riffles.

In addition to the coastal surveys, offshore transects were flown across the inlet. A sawtooth pattern of tracklines was designed to cross over shore at points approximately 30 km apart starting from Anchorage and zigzagging to the southern limits of Cook Inlet, between Cape Douglas and Elizabeth Island (Fig. 1).

Search Technique

Observers searched forward and laterally, but not behind the wing line. When away from shore, the search typically focused on a zone approximately 10° or more below the horizon

(1-2 km from the aircraft) and 10° to 60° to the left (or right) of the trackline. This zone was considered to have a relatively good probability for detecting whales.

The search area for observers on the shore side of the aircraft was bounded by the shoreline, 1.4 km (10°) from the trackline. The steepest angles observers could search were 81 to 86°, depending on the height of the observer relative to the window frame, but typically there may have been little search effort expended at angles exceeding 75° (0.07 km off the trackline). This would mean there was a 0.14 km (140 m) wide blind zone along the trackline. When the search was concentrated in the typical viewing area, 10° to 60° off the trackline 1-2 km ahead of the aircraft, there would have been reduced effort within 0.4 km of the trackline, possibly lowering sighting rates in a 0.8 km wide swath under the aircraft.

Sighting Records

Immediately on seeing a beluga group, each observer reported the sighting to the recorder. As the aircraft passed abeam of the whales, the observer informed the recorder of the species, inclinometer angle, whale travel direction, and notable behaviors. With each sighting, the observer's position (left front, left rear, etc.) was also recorded. The recorder repeated these entries back to the observer to confirm accuracy. An important component of the effort by the observers on the left was that they not cue each other to their sightings. They had visual barriers between them, and their headsets did not allow them to hear each other, but they could be heard by the recorder, and the recorder was able to selectively confirm their sighting information. As these data were being entered, the aircraft continued past each whale group until it was out of sight; then the aircraft returned to the group and began the circling routine. If one observer missed seeing a group on transect, there was no cue to the sighting until the aircraft turned to circle the group. The pilot and data recorder did not call out whale sightings or in any way cue the observers to the presence of a whale group.

Distance to Sightings

The distance between the location of the aircraft when an initial sighting was made and the location of the whale group gave an indication of the observers' effective search perimeter. The whale group location was established at the onset of the aerial passes by flying a criss-cross pattern over the group, recording starts and stops of group perimeters. The perimeter point closest to the aircraft's location at the initial sighting was used to calculate the sighting distance.

Counting Techniques

The flight pattern used to count a whale group involved an extended oval around the longitudinal axis of the group with turns made well beyond the ends of the group. Whale counts were made on each pass down the long axis of the oval. Because groups were circled at least four times (4 passes for each of two pairs of observers on the left side of the aircraft), there were typically 8 or more separate counts per group. Counts began and ended on a cue from the left front observer, starting when the group was close enough to be counted and ending when it went behind the wing line. This provided a record of the duration of each counting effort. The paired observers made independent counts and wrote down their results along with date, time, pass number, and quality of the count. The quality of a count (A through F) was a function of how well the observers saw a group, rated A if no glare, whitecaps, or distance compromised the counting effort, and rated down to F if it was not practical to count whales on that pass. These notes were not exchanged with anyone else on the aerial team until after all of the aerial surveys were completed. This was done to maximize the independence of each observer's estimates.

Typically, counting techniques involved a rapid tally from left to right across the whale group, mentally registering each surfacing whale as fast as possible or counting by fives or tens. Large groups were counted on a single visual pass across the group without looking back except slightly to include new surfacings close to the counting focus. This gave only a few seconds of search time on any particular beluga location. Dispersed or small groups allowed slightly longer counting efforts because it was easier to keep track of surfacings. Generally counts consisted of the number of visible whale backs, but if wakes, mud plumes ("contrails"), or other obvious indications of a whale's presence were included in a count, they were noted in comments. Aerial counts were of the number of sighting cues; later analysis would approximate the total number of whales present, whether or not they were visible from the aircraft.

When groups were circled, the right front observer moved to the co-pilot's seat and used a video camera through an open window to document the belugas. The camera was set on manual focus and operated at maximum useable shutter speeds (1/1000 to 1/10,000 sec, depending on available light). Date and time were recorded directly onto the video image. For compact groups of whales, magnification was adjusted to keep the entire group in view throughout the pass. Dispersed groups were better documented by maintaining the camera in a set position and at a constant magnification. As a study of the ability for the standard video (generally operated at 1 to 8 power) to capture whale images - especially gray juveniles, which are hard to detect - a paired video camera was operated at maximum magnification (15x). The two cameras were mounted on a board such that they had overlapping fields of view and were operated simultaneously during certain dedicated circlings over beluga groups.

On some tests, a still camera (Nikon F2) with 135 mm lens and Fuji 400 Provia film was used in the left rearmost position. This position had an opening window and allowed the camera to be fired perpendicular to the trackline. Prior to each aerial pass over a whale group, a photo of an identifiable marker (e.g., fingers held to show pass number) was taken by each camera.

Analysis

In each season from 1994 to 1996, whale groups were systematically video taped whenever possible. These video images were studied in the laboratory, and counts of whales were made to compare to the infield counts (see Waite and Hobbs 1995). Analysis of both the aerial counts and counts from the video tapes are described in Hobbs et al. (1995) for 1994 data. Hobbs et al. (1995), Lerczak (1995), and Waite et al. (1995) describe tagging operations used to establish corrections for whales missed during aerial counts of beluga whales.

Results

Survey Effort

A total of 39.73 hrs of aerial surveys were flown around Cook Inlet 11-17 June 1996. All of these surveys (10 flights ranging from 1.7 to 6.1 hrs) were based out of Anchorage. Systematic search effort was conducted for 20.60 hrs, not including time spent circling whale groups, deadheading without a search effort, or periods with poor visibility. Visibility and weather conditions interfered with the survey effort during only 0.13 hr (0.6% of the total effort) when one or more observers considered the visibility poor or worse. There were 7.5 hrs of video tape collected over whales. Results from video analysis will be reported in a separate document.

The first survey, on 11 June, was a reconnaissance flight targeting the delta of the Susitna River, an area where beluga whales have been found consistently during previous surveys. Counting techniques were practiced and dual videography was tested. Dual videography and photography tests were done again on whale groups in the Susitna delta on 17 June.

Stranded Belugas

We initiated a survey of upper Cook Inlet on 12 June, but the course was changed to study a group of stranded beluga whales, reported to us by a pilot in the Susitna area at 10:30. At the time of the report, the animals were already well above the waterline. We found the group on a mudflat south of the east margin of the Susitna River (61°11.24'N, 150°32.96W). From 10:55 to 11:21, we circled the group to document the stranding on video and to make counts. A total of 63 whales (55-61 by aerial estimates) were together in one discontinuous group; at least half (n = 28) were white, half (n = 27) were gray, and 4 were calves. When we first saw the group, it was approximately 100 m from the waterline. Whales were still thrashing, and some amount of movement was seen occasionally over this and the subsequent observation periods, at 12:32-12:38 and 13:22-14:04. Many gulls were nearby, but none were seen on the whales. Blood was visible on or near several whales. We left the area temporarily, returning when the tide was rising. From 13:36-13:55, as the tide flooded the stranding site, the whales began swimming again and moved away. Low tide (-1.7 ft) was at approximately 11:30. The animals swam away when the tide was approximately +12 ft. If the stranding also occurred at this tide height, then the whales may have been stranded from 08:30 to 14:00; that is, for 5.5 hrs. When the whales began to swim away, they moved slowly and went in different directions, but minutes later they came together and began traveling as a group going south toward deeper water. After the group swam free of the stranding, we conducted a series of standard aerial counts over the group. Using only A and B quality counts (some counts were compromised by glare), there were 21, 35, and 33 counted by one observer and 35, 32, and 32 counted by another. The median of these counts (33) is 52% of the known number (63) for the stranded group. It is not known how much the stranding may have affected the surfacing performance of these whales during the subsequent aerial counts.

Dead Belugas

On the same day, at 18:32 on June 12, a dead, floating beluga whale was seen in the Susitna delta 7.6 km north of the stranding site. Because the tide had been rising since the stranding, and the tide would carry flotsam to the north, it is possible this dead whale had been among the stranded animals. However, there was an extensive area of broken tissue on the exposed portion of the back (probably caused by the gulls seen on the carcass), and the carcass was floating, suggesting that the whale had been dead more than the 4.5 hrs observed since the end of the stranding. This area, the Susitna delta, is heavily hunted for beluga whales.

Another dead beluga whale was seen on 14 June mid-way between Pt. Possession and Anchorage. There was no evidence that the two sightings were or were not of the same animal.

Coastal Surveys

On 13 and 16 June, we flew coastal surveys of the perimeter of upper Cook Inlet north of East and West Forelands, including Knik Arm, Turnagain Arm, and the lower portions of the McArthur, Beluga, and Susitna Rivers. On 14 June, the survey covered the east shore of Cook Inlet from Pt. Possession to Elizabeth Island followed by sawtooth transects across the open water portion of the inlet back to Anchorage. On 15 June, a second set of sawtooth transects was flown that criss-crossed the first set, followed by a survey of the west shore of Cook Inlet from Cape Douglas to West Foreland, including St. Augustine and Kalgin Islands (Fig. 1).

Coverage

The composite of these aerial surveys provided a thorough coverage of the coast of Cook Inlet (1,388 km) for all waters within 3 km of shore (Fig. 1). In addition, there were 1,538 km of offshore aerial transects flown. Assuming a 2.0 km transect swath (1.4 km on the left plus 1.4 km on the right, less the 0.8 km blind zone beneath the aircraft), our coastal plus offshore tracklines covered 5,852 km^2, which means approximately 29% of the 19,863 km^2 surface area of Cook Inlet was surveyed. This calculation does not account for some intersections of offshore transect lines nor for the fact that observers generally searched well beyond 1.4 km. These surveys covered virtually 100% of the coastal area where beluga whales were expected.

Distance to Initial Sighting

Distances between the aircraft and a beluga group at the moment of the initial sighting ranged from 0.00 to 4.26 km (n = 47, combining data from 1994 to1996; Table 2 shows data from the 1996 survey). The mean sighting distance was 1.54 km (sd = 0.95). Half (49%) of the initial sightings occurred beyond 1.4 km, the perimeter of the standard viewing area. Distance to a group was positively correlated to the size of the group (Kendall distribution-free test for independence, $K^* = 1.95$, $p = 0.026$). Figure 2 demonstrates the frequency distribution of distances relative to whether the groups were small (<20) or large (>=20). This group size (20) formed a convenient definition because it split the sample size in half (21 of 40 groups had <20 whales each).

Distance at Closest Pass

Minimum distances between whale groups and the trackline ranged from 0.00 to 3.25 km, with a mean of 0.73 km (sd = 0.69; n = 50, combining data from 1994 to 1996; Fig. 3; Table 2 shows data from 1996). In 10 of 50 instances, the trackline went over a beluga group, and in 7 instances (14%) groups were more than 1.4 km from the trackline; 8% of small groups (<20 whales) and 22% of large groups were beyond 1.4 km at the closest pass.

Missed Groups

All four of the primary observers in 1996 had prior experience in surveying for beluga whales in Cook Inlet. Two other observers accompanied some of the flights, but they were not included in the inter-observer analysis because of the short time they were with the project. Results from June 1996 were combined with those from June 1994 (Rugh et al. 1995) and July 1995 (Rugh et al. 1996) to increase the sample size. These records do not account for the possibility of whale groups missed by all observers, a calculation which will be developed in a separate document.

Of 40 groups recorded in 1994-96, 17 were reported by only one primary observer and missed by the other, while 23 groups were reported by both observers. Whether or not an observer saw a whale group was affected in part by the size of the group. The mean group size of those missed by an observer ($\bar{x} = 23$; s.d. = 37) and groups reported by both observers ($\bar{x} = 79$; s.d. = 74) were significantly different ($z = -6.35$, $p << 0.01$). Most (70%) of the whale groups seen in the Susitna delta area were large (>20), and most (93%) of the groups seen elsewhere in Cook Inlet were small.

Distance also affected the probability of missing a group. Of 5 recorded groups that were >1.4 km from the trackline at the closest pass, only 2 (30%) were seen by both observers; of 33 groups within 1.4 km, 18 (55%) were seen by both; of 13 groups within 0.5 km of the aircraft, 10 (77%) were seen by both observers.

Observer performance affected sighting rates (Table 3). Two observers (B and C) had higher missed rates (40-50%) compared to the other four observers (5-19%). Individual observer's sighting rates varied from a mean of 0.31 groups/hr (observer B) to 0.80 groups/hr (observer A), with three observers (C, D, E) having nearly identical sighting rates (.58-.59 groups/hr). However, the amount of paired, independent search effort has varied among observers from 10.4 to 31.0 hrs, and the sample size is considered too small to be conclusive with the number of observers and the number of covariates that should be treated in this analysis.

In summary, we have isolated three parameters that have the potential for significantly affecting whether or not a beluga group was seen: group size (<20 vs. ≥20), distance (<1.4 vs. ≥1.4 km), and observer. These parameters probably have interactive components, such as group size and distance as a function of where an individual observer tends to search; however, sample sizes are too small to adequately test all of these components and to provide corrections based on each observer's performance.

Aerial Estimates of Beluga Group Sizes

Aerial estimates of group size were reviewed for differences as a function of count quality, subjectively rated from A to F, in 1995 and 1996. Mean estimates of each quality rating were compared to all higher ratings. Accordingly, F quality estimates (n = 6) were on average 74% of A, B, C, and D estimates; D estimates (n = 23) were 59% of A, B, and C; C estimates (n = 38) were 86% of A and B; and B estimates (n = 38) were 91% of A quality estimates. Only quality A and B estimates were used in the following analysis.

Aerial counts of beluga whales are shown in Table 4, and sighting locations are shown in Figure 4. These counts are the medians of each primary observers' median counts on multiple passes over a group. The consistency of locations of resightings between days, particularly the whales near the Susitna Rivers and whales in Chickaloon Bay, allowed us to combine results among survey days, assuming whales did not travel long distances within the survey period. Therefore, using median counts from each site, the sum of the counts ranged from 154 to 361. This sum is not corrected for missed whales. Calculations for whales missed during these aerial counts and an estimate of abundance will be developed in a separate document.

Discussion

In Cook Inlet, beluga whales concentrate near river mouths during spring and early summer, especially in the northwest corner of the inlet between the Beluga and Little Susitna Rivers (Fig. 2), described here as the Susitna delta. Fish also concentrate along the northwest shoreline of Cook Inlet, especially in June and July (Moulton 1994). Most of our sightings of beluga whales have been in the Susitna Delta (56% in June 1993; 81% to 91% in June/July 1994-96). This concentration apparently lasts from mid-May to mid-June (Calkins 1984) or later and is very likely associated with the migration of anadromous fish, particularly eulachon (*Thaleichthys pacificus*) (Calkins 1984; 1989). We found that whales were more concentrated in June 1994 and June 1996 than in July 1995, perhaps evidence of this seasonal effect. Elsewhere in upper Cook Inlet in June and July, we have consistently found a group of 20-50 whales in Chickaloon Bay, and sometimes other groups have been seen in Knik Arm (1-80), Turnagain Arm (7), and Trading Bay (1-31) . In lower Cook Inlet, we have occasionally seen small groups: 1 just south of West Foreland in 1993, 9 in Kachemak Bay in 1994, 2 in Iniskin Bay in 1994, and 14 in Big River in 1995. Only 0-4% of our sightings in June and July from 1993-96 have occurred in lower Cook Inlet (Table 5).

Others who surveyed in June (Calkins 1984) also found the majority of animals in the northwest corner of the inlet (88% of the sightings made 1974-79), but far fewer in July (15% in 1974-79). Calkins (1984) reported seeing 26 beluga whales in Redoubt Bay and 25 whales south of Kasilof River in June. In July, 44% of his sightings were in the lower inlet. These were in groups ranging in size from 11 to 100 found between the Forelands and Tuxedni Bay, most well away from the coast. Calkins (1979:40) indicated that belugas were "seen throughout the year in the central and lower Inlet." Our records from June/July 1993-96 found only 0-4% of the whales in lower Cook Inlet.

In almost none of our survey years (1993-96) have we made sightings of beluga whales in deep water well away from shore. The furthest offshore sighting was a single whale 9.3 km offshore in 1996 in water 19 m deep. This whale was barely moving at the surface. In 1994, a group of beluga whales was seen 2.2 km from shore, but this was over shallow shelf waters listed as <1 m deep at lower low tides (NOAA Nautical Chart #16660). In every case, beluga whale groups of more than 1 animal were seen on the shore side of the aircraft; sometimes whale groups were so large they were seen from both sides of the aircraft, but only once - with the single whale mentioned here - was a group seen only on the open water side of our tracklines.

There have been sightings of beluga whales in the Gulf of Alaska outside of Cook Inlet. Harrison and Hall (1978) saw belugas near Kodiak Island in March and July. Murray and Fay (1979) also found belugas near Kodiak Island, as well as in Shelikof Strait, south of Prince William Sound, and in Yakutat Bay. Leatherwood et al. (1983) recorded one beluga near the southwest entrance of Shelikof Strait on 6 August 1982, but no other belugas were seen by them on the north or south shores of the Alaska Peninsula. Some sightings have been made in Prince William Sound in March (Harrison and Hall 1978) and Yakutat Bay in May (Calkins and Pitcher 1977), September (R. Ream, NMFS, NMML pers. commun.), and February (B. Mahoney, NMFS, ARO pers. commun.), perhaps as occasional visitors from Cook Inlet (Calkins 1989). These sightings indicate that at least some of the time there are beluga whales in the northern Gulf of Alaska outside of Cook Inlet. However, no sightings of belugas were made during many intensive aerial surveys around the Alaska Peninsula (Brueggeman et al. 1989; Frost et al. 1983; Harrison and Hall 1978; Leatherwood et al. 1983; Murie 1959; NMFS unpubl. data) supporting the hypothesis that the Cook Inlet stock is isolated from stocks in the Bering Sea, and that the Cook Inlet stock is not widely dispersed.

Survey methods for the 1996 study were developed from similar studies in 1993 (Withrow et al. 1994), 1994 (Rugh et al. 1995), and 1995 (Rugh et al. 1996). The 1994, 1995, and 1996 studies were some of the most thorough and intensive surveys yet conducted for beluga whales in Cook Inlet. These were also among the first aerial surveys for cetaceans in which paired, independent observation efforts were conducted systematically throughout the studies, with whale counts kept confidential until the field projects were concluded. It became evident that observers without previous experience had low sighting rates relative to experienced observers. This may in part be due to a need for developing appropriate search images and search patterns, and may also be a function of becoming familiar with the complex research protocol. Results from new observers may be compared to trained observers for use in future analysis for surveys that might be conducted without trained observers; however, more studies are needed to document the consistency of sighting rates or variances between observers. Details on survey protocol can be found in Rugh (1996).

Whale groups could sometimes be seen over 4 km away, but most initial sightings were at the limits of the typical search zone: 10° below the horizon or 1.4 km from the aircraft. By keeping the aerial trackline 1.4 km offshore, the survey optimized opportunities for seeing belugas. Calculations of initial sighting distances are conservative because inevitably a few seconds lapsed between the first sighting of the group, the reporting to the recorder, and the computer entry that grabbed the GPS position. At 185 km/hr, there would be a 50 m error for every 1 second delay. On the other hand, group locations were often determined as the center of the group because the perimeters are difficult to define. This potentially overestimated sighting distances if the initial sighting was actually on the near side of the group.

The distribution of intial sightings, particularly as a function of group size (Fig. 2) suggests there are whale groups that are not recorded. Differences in sighting rates between large and small groups is often more a function of the number of sighting cues available than the total surface area of the group, except when a group is so dense it provides a large visual target. In our study in 1996, out of 14 whale groups recorded during systematic searches, 12 were seen by both of the primary observers. The groups seen by only one observer had counts of 7 and 41 whales respectively. In 1995, out of 14 groups, only 9 were seen by both observers; and in 1994, out of 15 groups only 6 were seen by both. These records do not include groups missed by both observers.

Aerial sightings of belugas were generally of white backs as the whales arched during a surfacing, although surface disturbances were included in the counts. Small, dark gray animals, such as calves or yearlings, were probably under represented in the aerial counts (see Hobbs et al. 1995 for calculations of number of animals missed in the aerial counts). The number of beluga whales counted at the surface was inconsistent between aerial passes. This was in part due to changes in visibility, such as glare, but also due to changes in the amount of time the group was counted. Although there was not a constant number of animals in view, as might be expected if there was a random surfacing rate, we did not observe an apparent synchrony in surfacings either. Calkins (1979) describes waves of three sub-groups surfacing in synchrony within a larger group such that the first group is resurfacing as the third group submerges. We did not see any patterned surfacings of this sort.

The proximity of the aircraft to belugas did not seem to reduce sighting opportunities as the whales showed no apparent reaction to the survey aircraft. This is consistent with observations in other years (Withrow et al. 1994; Rugh et al. 1995, 1996) and may be due to habituation to the dense air traffic in the area. Our aircraft was not a novel stimulus: during most of our surveys in Upper Cook Inlet, many other aircraft were in view at any one time.

The uncorrected sum of median estimates made from the June 1996 aerial observations in Cook Inlet ranged from 154 to 361 beluga whales. Using the same procedure of summarizing median estimates from the highest seasonal counts at each site, there were 344 beluga whales in June 1993, 287 in July 1993, 157 in September 1993, 279 in June 1994, 338 in July 1995, and 361 in June 1996 (Table 5). The process of using medians instead of maximum numbers reduces the effect of outliers (extremes in high or low counts) and makes the results more comparable to other surveys which lack multiple passes over whale groups. Medians or means are also more appropriate than maximums when counts will be corrected for missed whales. Not until the respective correction factors have been applied will absolute abundances or inter-year trends be calculated.

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Table 1. Tidal conditions at the Susitna River delta when counts of beluga whales were made. Tide times were estimated as 1.0 hr prior to reported times for the NOAA Harmonic Station in southern Knik Arm, near Anchorage (61°14'N 149°53'W).

Date (1996)	Survey time	Tide time	Tide height (ft)	Counts of belugas	Number of groups
11 June	11:50-13:42	low 11:00	-0.4	126	4
12 June	12:46-13:19	low 12:00	-1.7	160	4
12 June	17:39-18:29	high 17:30	+26.7	125	4
13 June	13:18-15:09	low 13:00	-2.1	154	3
16 June	14:39-16:36	low 14:00	-1.2	237	4
17 June	14:02-17:43	low 14:30	-1.0	291	4

Table 2. Initial sighting information on each group of beluga whales recorded during the June 1996 survey in Cook Inlet. Group size is the median estimate made by all observers doing counts on that pass. An underline indicates which observer first saw a group. An x indicates which observers missed a sighting while on transect. Observers A and B were in previous year's surveys and did not return in 1996; observers G and H flew on only a few of the surveys in 1996 and are not included in subsequent analysis.

Date	Flt	Grp	Location	Group size	Left Front obsv	Left Mid obsv	Left Rear obsv	Right Front obsv	Initial Sighting Distance (km)	Closest dist. (km)
11 June	1	1	S of Beluga R.[1]	1	----	----	----	F	0.69	0.69
	1	2	Beluga R.	7	D	Cx	Gx	----	2.76	0.71
	1	3	Beluga R.[1]	1	----	----	----	F	----	----
	1	4	Theodore R.	4	D*	C*	G?*	----	1.10	0.00
	1	5	Lewis R.	113	D*	C*	G?*	F*	"	"
12 June	2	1	Knik Arm	6	E*	F*	G?*	----	1.22	0.13
	2	2	Knik Arm	2	----	----	----	C	----	----
	2	3	Stranded on Susitna Delta	61	----	----	----	----	----	----
	2	4	Pt Possession	----	E	Fx	Gx	----	2.39	0.97
	2	5	Lewis R.	127	----	----	----	C	0.53	0.53
	3	1	Theodore R.	19	F	C	G	----	0.99	0.82
	3	2	Lewis R.	14	F	C	G	----	----	----
	3	3	Big Su R.	92	F	C	G	----	1.23	0.00
13 June	4	1	Knik Arm	8	E	C	G	----	0.93	0.13
	4	2	Knik Arm	9	E*	C*	G*	----	----	----
	4	3	Pt Possession	41	Ex	C?	G	----	3.28	3.25
	4	4	Ivan R.	77	F	D	G	----	4.26	0.52
	4	5	Big Su R.	77	F*	D*	G*	----	----	----
14 June	5	1	Pt MacKenzie	20	----	----	----	E	2.57	2.27
16 June	9	1	Knik Arm	16	D*	C	H	----	0.47	0.37
	9	2	Knik Arm	13	D*	C	Hx	----	0.96	0.95

Table 2. (Cont.).

Date	Flt	Grp	Location	Group size	Left Front obsv	Left Mid obsv	Left Rear obsv	Right Front obsv	Initial Sighting Distance (km)	Closest dist. (km)
	9	3	Pt Possession	21	D	C	H	----	2.75[2]	1.84
	9	4	Lewis/ Ivan R.	114	F	E	H	----	4.06	0.98
	9	5	Big Susitna	47	C	D	H	----	2.19	1.03
	9	6	Big/ Little Su	59	E	F	H	----	2.95	1.11
	9	7	Little Su Delta	17	E*	F*	H*	----	2.42	1.52
17 June	10	1	Ivan/ Big Su R.	263	H*	E*	F*	D*	----	----
	10	2	Big Su R.	----	H*	E*	F*	D*	----	----
	10	3	Little Su R.	28	H*	E*	F*	D*	----	----
	10	4	Ivan/ Big Su R.	78	H*	E*	F*	D*	----	----

[1] This "group" was a single whale near group 2.
[2] Observer "H" saw this group at 4.40 km but with the assistance of binoculars.
*There was open communication between observers, so sightings were not included in inter-observer analysis. In some cases, indicated by a question mark (?), it was not clear whether the respective observer saw the group independently.

Table 3. Pairings of primary observers (left front and middle positions only) during aerial surveys over Cook Inlet in June/July 1994-96, showing the number of beluga whale groups reported by each observer while paired. Each of the observers in the top row was compared to the respective paired observer in the leftmost column.

Paired Observers		Observers A	B	C	D	E	F
A	1994	---	5	0	3	---	---
	1995	---	0	0	2	2	---
	1996	---	---	---	---	---	---
B	1994	5	---	0	0	---	---
	1995	2	---	0	1	0	---
	1996	---	---	---	---	---	---
C	1994	2	0	---	4	---	---
	1995	2	0	---	1	3	---
	1996	---	---	---	3	1	3
D	1994	2	0	2	---	---	---
	1995	1	0	0	---	4	---
	1996	---	---	2	---	0	1
E	1994	---	---	---	---	---	---
	1995	3	0	3	3	---	---
	1996	---	---	2	0	---	2
F	1994	---	---	---	---	---	---
	1995	---	---	---	---	---	---
	1996	---	---	3	1	3	---
Total groups seen	1994	9	5	2	7	---	---
	1995	8	0	3	7	9	---
	1996	---	---	7	4	4	6
Total seen by one or both observers	1994	12	7	6	7	---	---
	1995	9	3	6	8	10	---
	1996	---	---	8	4	5	7
Groups missed	1994	3	2	4	0	---	---
	1995	1	3	3	1	1	---
	1996	---	---	1	0	1	1

Table 3. (Cont.).

		Observers					
		A	B	C	D	E	F
Large groups (>20) missed		1	2	3	0	1	0
Percent missed		0.19	0.50	0.40	0.05	0.13	0.14
Hours	1994	14.2	9.7	10.2	11.8	0	0
surveyed	1995	7.0	6.2	5.7	9.6	11.7	0
while paired	1996	0	0	10.6	9.6	10.5	10.4
Groups/hour		0.80	0.31	0.45	0.58	0.59	0.58

Table 4. Summary of counts of beluga whales made during aerial surveys of Cook Inlet in June 1996. Medians from experienced observers counts were used from aerial passes where observers considered visibility good or excellent (conditions B or A). Dashes indicate no survey, and zeros indicate that the area was surveyed but no whales were seen. Sites are listed in a clockwise order around Cook Inlet.

	Flight dates in June 1996							
Location	11 June	12 June	13 June	14 June	15 June	16 June	17 June	Min-max Counts
Turnagain Arm	---	0	0	---	---	0	---	0
Chickaloon Bay	---	*	41	---	---	21	---	21-41
Kenai River	---	---	---	0	---	---	---	0
Kachemak Bay	---	---	---	0	---	---	---	0
Iniskin Bay	---	---	---	---	0	---	---	0
Big River	---	---	---	---	0	---	---	0
McArthur River [a]	---	---	0	---	---	0	---	0
Big Su Delta [b]	126	160 (or 125)	154	---	---	161	263	125-291
Little Su River	0	0	0	---	---	76	28	(b)
Knik Arm [c]	---	8	17	20	---	29	---	8-29
								Total = 154-361

* Beluga group seen but not counted.
(a) Includes all of Trading Bay.
(b) Includes all groups between Beluga River and Little Susitna River.
(c) Includes Pt. Mackenzie.

Table 5. Summary of beluga whale sightings made during aerial surveys of Cook Inlet. Medians were used when multiple counts occurred within a day, and the high counts among days were entered here.

			Percent Sightings		
Year	Dates	Counts	Lower Cook Inlet	Susitna Delta	Elsewhere in Upper Cook Inlet
1993	June 2-5	344	0	56	44
1993	July 25-29	287	0	74	26
1993	Sept 3, 19	157	9	16	75
1994	June 1-5	279	4	91	5
1995	July 18-24	338	4	89	7
1996	June 11-17	361	0	81	19

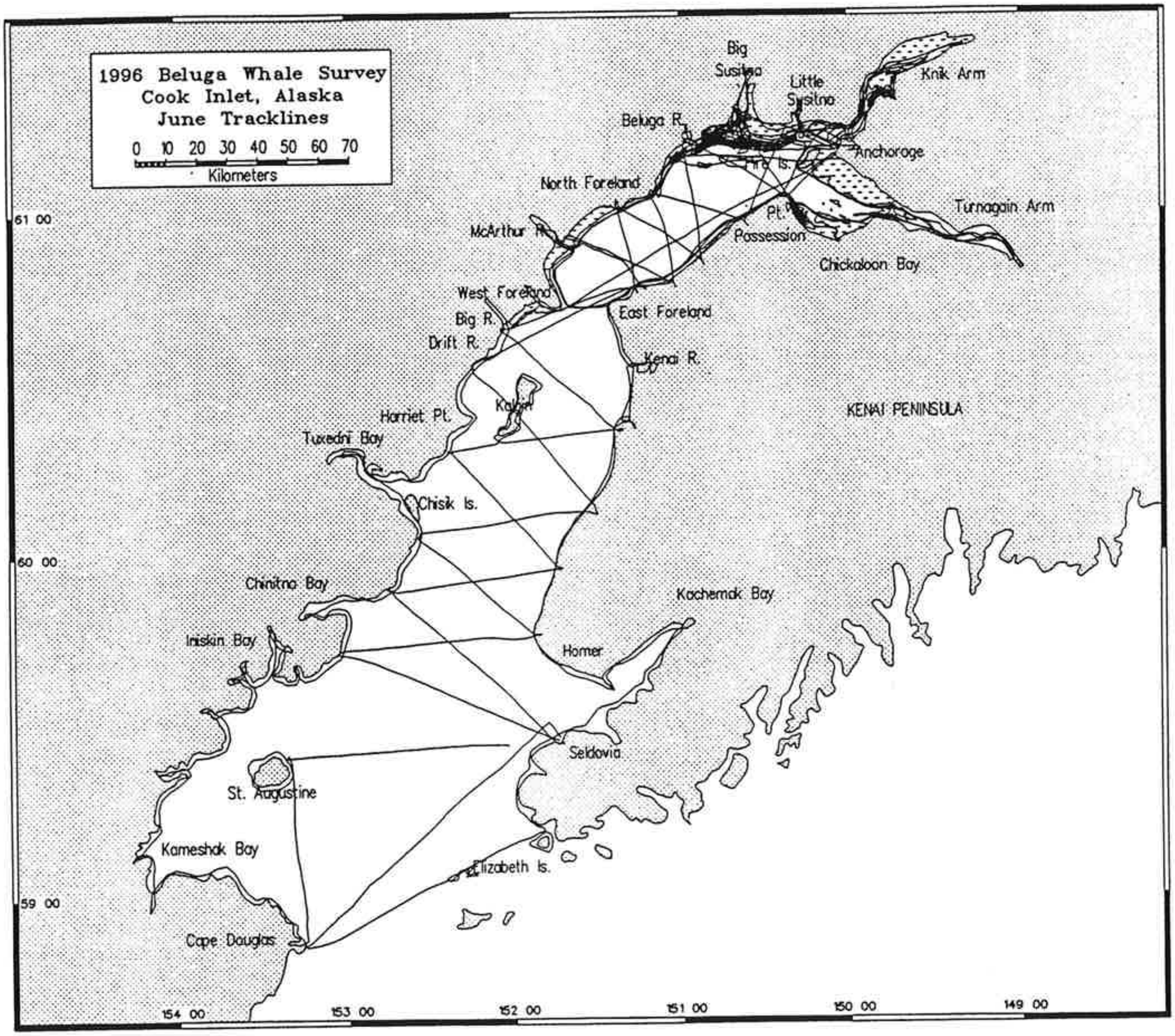

Figure 1. Aerial survey tracklines for 11-17 June 1996 covering the coastal and offshore areas of Cook Inlet. Dashed areas indicate mud flats exposed at low tide.

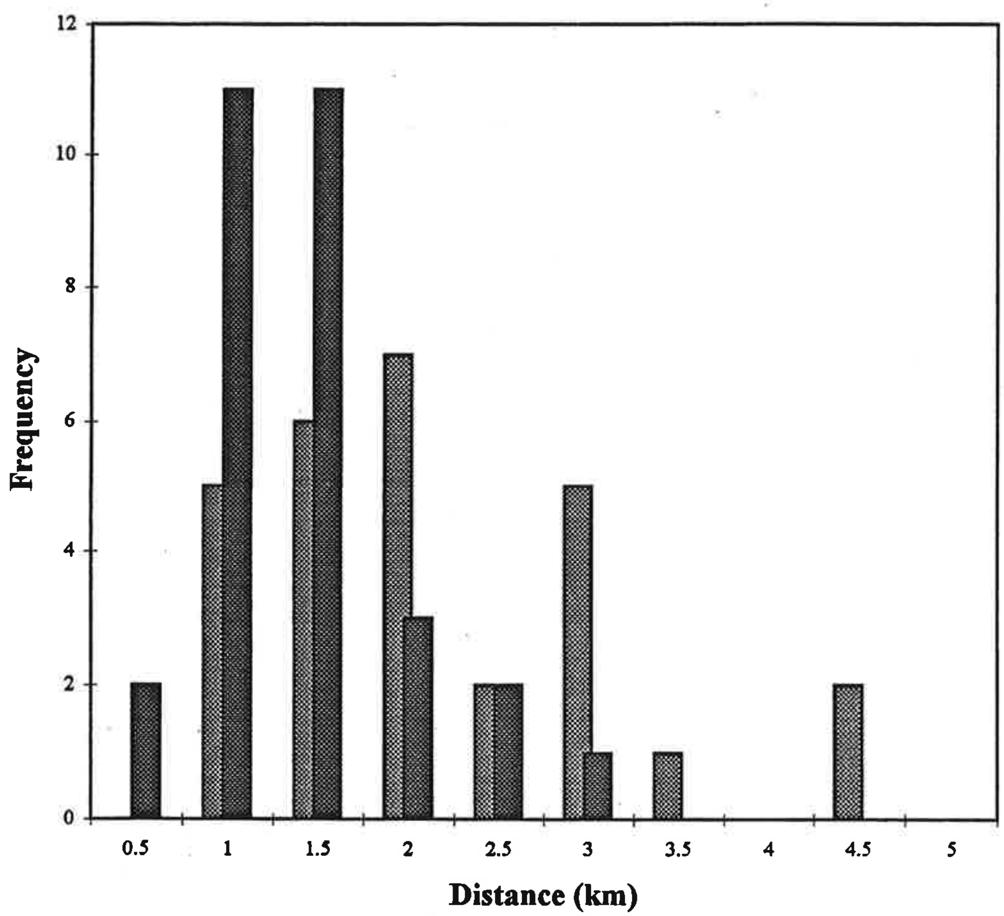

Figure 2. Distance between the aircraft and beluga groups when they were initially sighted. Black bars indicate groups of less than 20 animals each; gray bars indicate groups of more than 20.

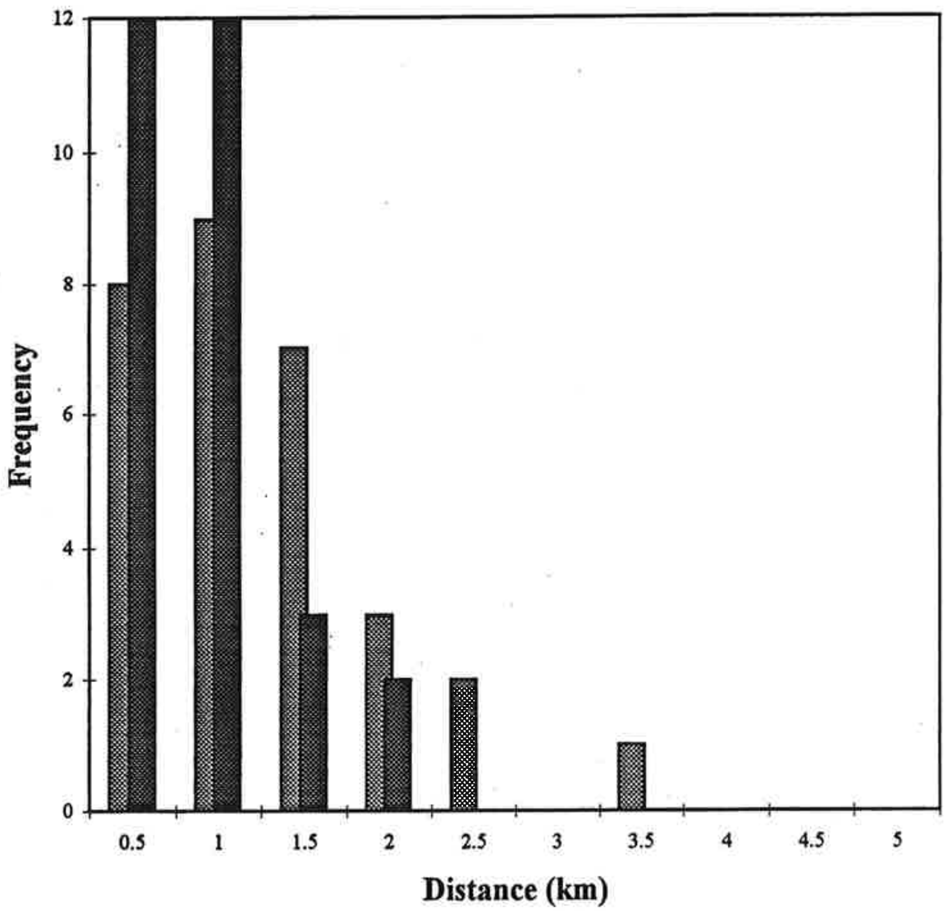

Figure 3. Distance between the aerial trackline and beluga groups at the closest pass. Black bars indicate groups of less than 20 animals each; gray bars indicate groups of more than 20.

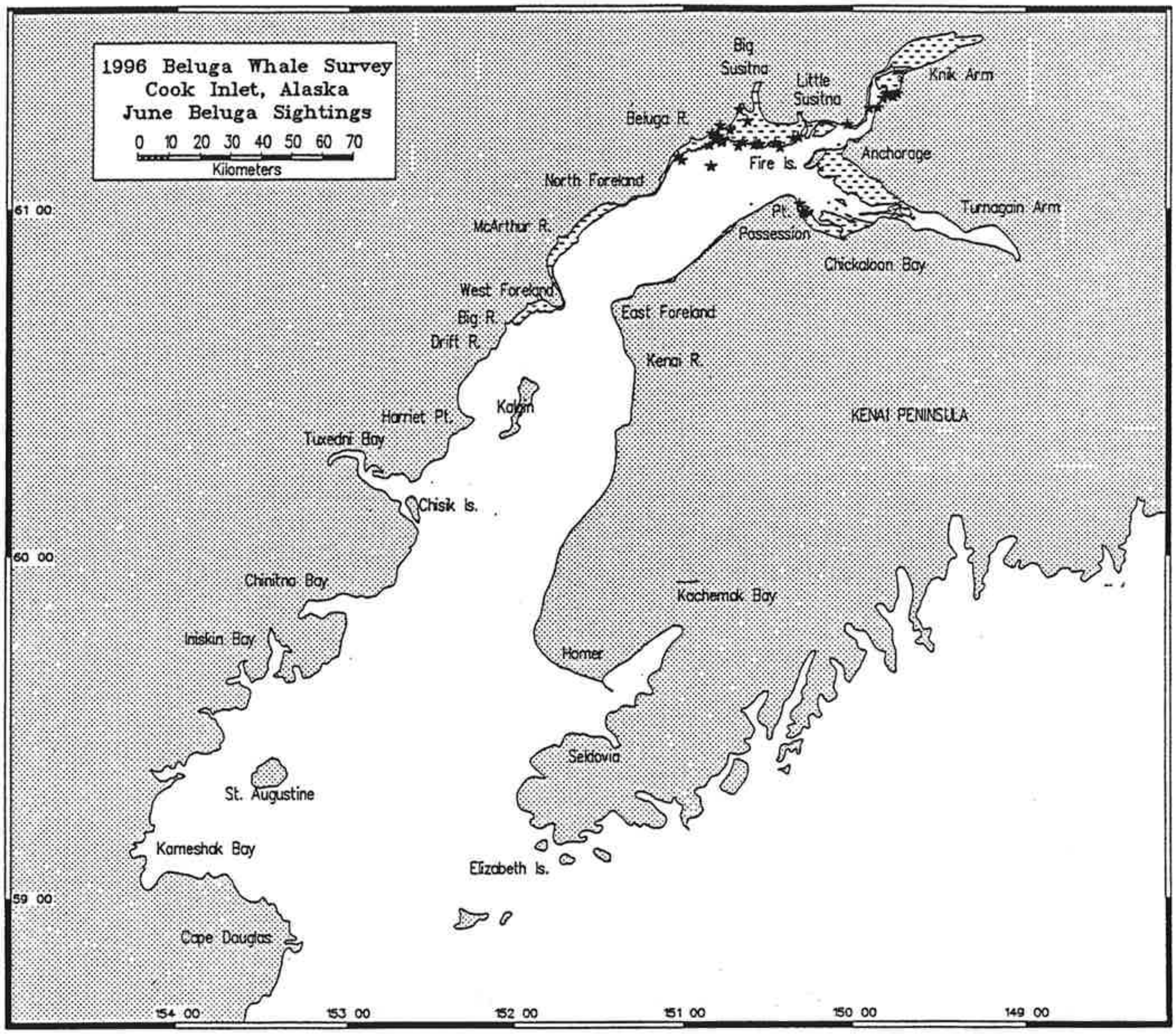

Figure 4. Beluga whale groups seen during aerial surveys of Cook Inlet 11-17 June 1996. Each star represents one sighting.

EVALUATION OF THE LIFE HISTORY PARAMETERS AND BREEDING SEASON DISTRIBUTION OF CALIFORNIA SEA LIONS (*Zalophus californianus*) FROM A BRANDING STUDY AT SAN MIGUEL ISLAND, CALIFORNIA

Sharon Melin, Robert L. DeLong, and Jeffrey L. Laake

National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington, 98115

Abstract

Individual identification of animals via natural or man-made marks provides an effective method of assessing basic biological data on long-lived species and enables measurement of vital rates that are needed to understand their population dynamics. In 1987 a branding program for California sea lions (*Zalophus californianus*) was initiated to obtain information on age at first reproduction, age-specific natality rates, survival rates and coastal distribution. The results from observations along the California coast during the 1996 breeding season are presented.

Sea lions have been resighted from each cohort branded between 1987 and 1995. An average of 31.3% of each female cohort and 26.1% of each male cohort were resighted in 1996. The distribution of sightings along the California coast suggests that age and sex segregation occurred among haulout sites; San Miguel Island and Año Nuevo Island were the primary haulout areas. Most individuals (80.3%) used only one area during the season reinforcing the need to resight sea lions at several sites to minimize bias in survival rate estimates.

Annual survival rate estimates based on resighting data from 1991 to 1996 varied with age and sex. Pup survival depended on the pup's weight at branding and the El Niño event in 1992/1993. Annual survival estimates for male sea lions were 0.75 (SE=0.05) for yearlings and 0.87 (SE=0.02) for ages 2 years and older. Annual survival rate estimates for female sea lions were 0.83 (SE=0.05) for yearlings and 0.95 (SE=0.01) for ages 2 years and older.

Females of ages 5 to 9 years old were sighted with pups. Age-specific natality rates ranged from 36.6% to 56.8%; the annual natality rate was 35.2% (43.4% excluding 4 year olds). Less than 40% of females with pups were continuous breeders. Additional years of resight effort at the primary haul-out locations are needed to more precisely estimate age-specific natality rates, survival rates and age at first reproduction and evaluate annual variability.

Introduction

California sea lions (*Zalophus californianus*) are an abundant pinniped along the California, Oregon and Washington coasts. Although the behavioral aspects of their life history have been well described (Peterson and Bartholomew 1967, Odell 1981, Heath 1989), there have been no comprehensive studies to estimate their life history parameters such as age at first reproduction, age-specific natality and age-specific survival rates. Life history parameters are an important component in understanding population dynamics.

In 1987, a long-term branding and resighting study was initiated to describe the life history parameters and the movement patterns of the California sea lion population at San Miguel Island, California. The goals of the study were to 1) obtain longitudinal records of known-age individuals to estimate age at first reproduction, age-specific natality rates and age-specific survival rates, and 2) document movements and distribution of known-age individuals. Estimates of life history parameters can be used with an age-structured population model to provide a correction factor for pup counts to produce total sea lion population estimates. Additionally, annual variation in life history parameters relative to population size can increase our understanding of California sea lion population dynamics and mechanisms of density dependence.

The ultimate objective of the branding study is to assess the status of the California sea lion population relative to maximum net productivity levels (MNPL). It is a particularly important objective for the California sea lion population because interactions between California sea lions, humans and fisheries are increasing proportionally to the population. In some cases, these interactions are contributing to the demise of other species in the ecosystem (Gearin et al. 1988). If the sea lion population continues to increase at the current rate of 6.4% per year, management of sea lions in areas where they are in conflict with humans and fisheries may be required and information on the population dynamics will become critical for making effective management decisions.

The primary breeding areas of California sea lions are the California Channel Islands and offshore islands of Baja California, Mexico (Fig. 1). Hauling areas occur from Mexico northward to Vancouver Island, British Columbia, including the breeding islands, however hauling sites north of the Farallon Islands are only occupied during the winter migration by males. Besides the breeding islands, sea lions have several preferred hauling areas along the central and northern California coast where large aggregations occur year around. These areas include the Big Sur coast (Cape San Martin, Grimes Point, Seal Rock), Monterey Bay, Año Nuevo Island, San Francisco Bay, and the Farallon Islands (Fig. 2).

To obtain accurate estimates of the vital parameters of sea lions, all age and sex classes must be sampled. Sampling all age and sex classes is complicated by the expansive range of sea lions and because at no time during the year are all age and sex classes of California sea lions present at any hauling or rookery area. During the breeding season, however, the range is contracted to primarily the breeding islands and the central and northern California hauling sites. This characteristic of behavior makes the breeding season the most feasible time to survey for marked individuals and the most likely time to observe the greatest proportion of all the age and sex classes.

Prior to 1994, all observation effort of marked animals was conducted at San Miguel Island under the assumption that California sea lions would have fairly high natal site fidelity. However, a study in 1994 indicated that juveniles were primarily hauling out at Año Nuevo Island during the breeding season suggesting that observation effort only at San Miguel Island may result in underestimating juvenile survival (Birch and Ono, in prep). Thus in 1996, four major hauling sites were surveyed for marked animals during the breeding season to better estimate survival parameters.

Methods

From 1987 through 1995, California sea lion pups at San Miguel Island, California, were permanently marked using hot brands. Pups were 4 to 5 months old when branded. Each pup was branded on the left or right shoulder with a unique number and tagged in the foreflippers with yellow roto tags. The tags facilitate location of branded animals in large groups and provide a returnable identification for animals found dead on beaches or in nets.

Observations of branded animals and the reproductive status of sighted animals were recorded throughout the breeding season (May through August) at seven study areas along the California coast: San Miguel Island, Grimes Point, Cape San Martin, Seal Rock, Monterey Bay, Año Nuevo Island, and the Farallon Islands (Fig. 1). Animals were identified using binoculars or a 20X to 60X zoom scope. Sighting effort was recorded as the number of hours devoted each day to sighting branded animals. Sighting effort was logged from June through early August.

Females were considered reproductive in 1996 if they were sighted nursing a pup. Age at first reproduction is estimated as the minimum age females were sighted with pups. The average age at first reproduction was not calculated because females sighted with a pup for the first time at 8 and 9 years old may have had pups in previous years (see discussion for sighting probability affects). Age-specific natality was defined as the number of females with pups at each age relative to the total number of females known to be alive of each age. The annual natality rate was defined as the number of females with pups relative to the total number of females alive that could have pups. Future analyses will include sighting probability in the analysis of natality rate.

Survival rates were estimated using the computer program MARK developed by Dr. Gary White at Colorado State University. The program is under development and a published reference is currently unavailable. MARK provides estimates of sighting probability and survival rate for general open population capture-recapture models (e.g., Jolly-Seber) and allows models to specify time- and individual-specific covariates for resighting and survival probabilities. We fitted a variety of models to the data for male and female sea lions which included covariates for age, year, pup weight at branding, and the occurrence of El Niño events.

Results

1996 Resighting Survey

The number of sightings per hour of branded animals was greatest at San Miguel Island (6.4) and Año Nuevo Island (5.3) (Table 1). Monterey Bay had a lower sighting frequency of 2.6 branded animals per hour and the Big Sur coastal areas (Seal Rock, Grimes Point, Cape San Martin) and the Farallon Islands had less than one sighting per hour of observation time.

A total of 1,161 individual branded animals were sighted at four study areas (Table 2). Sightings for the Big Sur coastal areas were combined with the Monterey Bay sightings for analysis because of low sample sizes. Most sightings of branded animals (68.4%) occurred at San Miguel Island followed by Año Nuevo Island (23.4%), Monterey Bay (6.0%), and the Farallon Islands (2.2%) (Table 2).

Of branded individuals sighted at the four areas, 932 (80.3%) were sighted at only one area (unique sightings) and 229 (19.7%) were sighted at two or more areas (duplicate sightings) (Table 2). Most unique sightings occurred at San Miguel Island (75.9%) followed by Año Nuevo Island (18.2%), Monterey Bay (3.5%), and the Farallon Islands (1.8%). More males (22.8%) than females (6.1%) were sighted at two areas. Most animals sighted at two areas were sighted at San Miguel and Año Nuevo Islands (61% males; 63.2% females). Two females and one male were sighted at three of the four study areas.

All cohorts were represented during the breeding season in 1996. The average percentage of each cohort that was sighted in 1996 was 31.4% for females (n=9, SE=2.0%, range 21.3-39.8) and 26.1% for males (n=9, SE=2.0%, range=15.7-38.8) (Tables 3 and 4).

San Miguel (78.6%) and Año Nuevo(15.8%) Islands were the primary areas for sightings of females (Fig. 3). Monterey Bay (4.3%) and the Farallon Islands (1.3%) accounted for less than 6% of the female sightings. Males were also sighted primarily at San Miguel (52.9%) and Año Nuevo (35.0%) Islands, but Monterey Bay (8.6%) and the Farallon Islands (3.5%) accounted for 12% of the male sightings (Fig. 3). The northern hauling sites (Monterey Bay, Año Nuevo Island, and the Farallon Islands) accounted for 47.1% of the male sightings compared to 21.4% for females.

No adult males were sighted in 1996 (i.e. no males were sighted holding territory). Adult females and subadult males were sighted primarily at San Miguel Island (91.1% females; 68.7% subadult males) (Figs. 4 and 5). Most juvenile (80.0%) and yearling (69.7%) females were sighted at San Miguel Island but those that left San Miguel Island were sighted primarily at Año Nuevo Island (21.6% juveniles; 21.3% yearlings) followed by Monterey Bay (4.6% juveniles; 11.6% yearlings), and the Farallon Islands (0.70% juveniles; 2.9% yearlings).

More juvenile males (47.9%) and yearlings (40.3%) were sighted at Año Nuevo Island than at any other site. Juveniles were sighted in decreasing frequency at San Miguel Island (31.7%), Monterey Bay (18.2%) and the Farallon Islands (3.2%). Yearlings followed the same pattern as juveniles, decreasing in frequency at San Miguel Island (25.8%), Monterey Bay (21%), and the Farallon Islands (12.9%).

Although adult females were sighted at all areas, females with pups were sighted only at San Miguel Island. Of 301 females sighted that were of reproductive age (age 4 or older), 35.2%were sighted with pups in 1996 (Table 5). Although 4-year-old females have been sighted with pups (DeLong and Melin, unpublished data), females with pups ranged in age from 5-9 years suggesting that age at first reproduction was 5 years in 1996. Age-specific natality rates ranged from 36.6% to 56.8% and increased, in general, with age. Of the females with pups, 22.6% have been sighted with pups in two consecutive years, 13.2% in 3 years and 1.8% in 4 years. The remaining females were sighted with pups for the first time in 1996 (56.6%) or had skipped years (5.7%).

Survival Rates

Estimates of annual survival rates for females were based on 2,085 uniquely branded sea lions (25 were excluded for missing data). During June and July in 1990-96, 1,859 resightings of 1,065 branded females were made. Of those branded, 1,020 females have never been resighted, but 404 are from 1994 and 1995, which have had only 2 and 1 occasions for resighting, respectively. During 1994-96 with 500 to 600 hrs of effort combined at San Miguel and Año Nuevo Islands (no effort in 1995) in each year, 50-60% of 2+ year old and 30% of yearling female sea lions alive at the time of the survey were resighted in each year. Resighting probability was much lower prior to 1994 because less effort was given to resighting. Survival varied with age but with the current data differences were only found to 2 years of age (Table 6). Female pup survival (from the time of branding to age 1) was dependent on the pup's weight at branding and was significantly lower in 1992 and 1993 when a moderate El Niño event occurred (Table 6). Pup survival during non-El Niño years is estimated to have ranged from 0.65 to 0.98 for pups weighing 7 kg to 29 kg at time of branding, respectively.

Estimates of annual survival rates for males were based on 1,460 uniquely branded sea lions (11 were excluded for missing data). During June and July in 1990-96, 1,146 resightings of 682 branded males were made. Of those branded, 778 males have never been resighted, but 308 are from 1994 and 1995, which have had only 2 and 1 occasions for resighting, respectively. During 1994 and 1996 with 500 to 600 hrs of effort combined at San Miguel and Año Nuevo Islands (no effort in 1995) in each year, 50-60% of 2+ year old and 35-40% of yearling male sea lions alive at the time of the survey were resighted in each year. During 1995 with an equivalent level of effort only at San Miguel Island, only 29% of the 2 and 3 year-old males were seen and 18% of the yearling males were seen. The effort in Northern California is particularly important for resighting male sea lions and during El Niño events when females shift farther north. Survival varied with age but with the current data differences were only found to 2 years of age (Table 7). Male pup survival (from the time of branding to age 1) was dependent on the pup's weight at branding and was somewhat lower in 1992 and 1993 when a moderate El Niño event occurred (Table 7). Pup survival during non-El Niño years is estimated to have ranged from 0.66 to 0.99 for pups weighing 12 kg to 33 kg at time of branding, respectively.

Discussion

The branding program is providing important information on the biology and distribution and movements of California sea lions.

1. Observations at the major hauling sites of California sea lions along the California coast indicate segregation of the population by both sex and age and a limited degree of individual movement between the study sites during the breeding season.

2. Survival rates vary by sex and age and pup survival is dependent on weight and the occurrence of El Niño events.

3. Males are more likely to move to Northern California as pups which may explain why their survival during the first year was reduced less than females during the 1992-93 El Niño event.

4. Both male and female survival rates are considerably higher than fur seals (Lander 1981). Although we expected to see decreases in survival with age, we currently do not have a sufficient sample size of older animals to test for this effect because the initial branded cohorts were small.

Our assessment of survival rates is preliminary and will be improved as more resighting data are collected and as the model of resighting probability is improved. The ease of re-sighting brands provides resighting probabilities that are much higher than most capture-recapture studies. Although, the resighting probabilities are high, the assumed model of resighting probability influences the survival estimates to some degree because of the non-random distribution of the age and sex-classes. To counter this non-randomness, it is essential that resighting effort be conducted throughout the animal's range. It is essential that resighting effort be continued to some degree along the coast of California to increase the validity of the estimates by reducing their dependence on the assumed model of resighting probability. Research on long-lived species requires long-term studies and while we have obtained some initial estimates of survival and reproduction, it is important to recognize that until we have followed cohorts through their natural life, our assessment is incomplete.

Our estimates of age at first birth and age-specific natality will also be improved as more data are collected. From current data, adult females appear to have significant site fidelity once they become reproductive. Although adult females were sighted at all study areas, reproductive females were sighted only at San Miguel Island. Less than 40% of females sighted with pups in 1996 were continuous breeders, suggesting that most females do not reproduce in every year. The youngest females sighted with a pup in 1996 were 5 years old indicating that although a few females have been sighted with pups at 4 years of age (DeLong and Melin, unpublished data), the minimum age at first birth for females is 5 years.

Age-specific natality appears to be similar to northern fur seals (*Callorhinus ursinus*) in that young females have lower natality rates than older females (Lander 1981). However, the natality rates of age classes 7 (36.6%) to 9 (56.8%) are lower than the pregnancy rates reported for northern fur seals (over 80% in 8 to 16 year olds) (Lander 1981). To more accurately determine the average and range of age at first reproduction and age-specific natality rates, a larger sample size is needed because of considerable individual variability in the values of these parameters.

Many factors affect sighting probability, but for adult females the most important is reproductive status. Females with pups are more likely to be sighted than females without pups, but the probability of sighting a female with her pup decreases over the breeding season as pups become more mobile. However, all breeding areas at San Miguel Island were surveyed at regular intervals (generally every other day) to increase the probability that a female would be sighted if she was present during the breeding season. The number of females with pups sighted at San Miguel Island is probably a reasonable representation of the number of females present during the 1996 breeding season.

Annual variability in sea lion distribution must be considered when interpreting which areas are important to sea lions. The distribution of California sea lions among the four areas is largely determined by the annual and seasonal distribution of their prey. For example, in 1982 and 1983, large aggregations of sea lions occurred at the Farallon Islands (Ainley et al. 1982, Huber

1991) and from 1992 through 1994, Monterey Bay and the central California coast sites served as haulout sites for large numbers of juvenile and sub-adult male sea lions (Browne 1995; Birch and Ono, in prep). However, during this study, fewer animals hauled out in these areas indicating that the importance of these areas is variable. In contrast, San Miguel Island and Año Nuevo Island are primary haulout sites every year.

Acknowledgments

We thank the personnel at the National Marine Mammal Laboratory, the Southwest Fisheries Center, the Channel Islands National Park, and all the volunteers who participated in the annual branding and tagging activities. We also thank T. Orr, Moss Landing Marine Laboratories; M. Hester, Point Reyes Bird Observatory; and J. Elliot, University of California, Santa Cruz, for collecting data from Monterey Bay, the Farallon Islands, and Año Nuevo Island.

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Table 1. Survey effort for branded California sea lions along the California Coast, June-August 1996.

Area	Survey period	Number of survey days	Number of survey hours	Total number of sightings	Sightings per hour
San Miguel Island	3 Jun-30 Jul	53	264.0	1,693	6.4
Grimes Point	3 Jun-27Aug	4	4.0	1	<1.0
Cape San Martin	3 Jun-27Aug	6	6.0	0	---
Seal Rock	3 Jun-27Aug	6	4.5	3	<1.0
Monterey Bay	3 Jun-27 Aug	12	14.5*	66	2.6*
Año Nuevo Island	5 Jun-8 Aug	28	122.3	648	5.3
Farallon Islands	13 Jun-25 Jul	16	52.8	32	<1.0

* Effort is based on 38 sightings for which effort was logged; the remaining 28 sightings were opportunistic.

Table 2. Number of sightings of branded animals sighted at four study areas along the California coast, June-August 1996.

Area	Number of individuals sighted	Number of unique sightings*	Proportion of individuals sighted per area	Proportion of unique sightings per area
San Miguel Island	794	708	0.684	0.760
Monterey Bay Coast	70	33	0.060	0.035
Año Nuevo Island	272	174	0.234	0.187
Farallon Islands	25	17	0.022	0.018
Total	1161	932		

* Unique sightings are sightings of individuals observed at only one area during the season.

Table 3. Total number of unique sightings and proportion of each cohort sighted of female branded California sea lions at four study sites along the California coast, June - August 1996.

Year branded	Age Class	Number branded	Number sighted	Proportion of cohort observed
1987	Adult	113	44	0.389
1988		97	27	0.278
1989		110	41	0.373
1990		250	76	0.304
1991		262	56	0.214
1992		235	57	0.243
1993	Juvenile	350	120	0.343
1994		367	140	0.381
1995	Yearling	326	96	0.294
Total		2110	658	0.312

Table 4. Total number of unique sightings and proportion of each cohort sighted of male branded California sea lions at four study sites along the California coast, June - August 1996.

Year branded	Age Class	Number branded	Number sighted	Proportion of cohort observed
1987	Subadult	87	18	0.207
1988		83	13	0.157
1989		90	20	0.222
1990		251	64	0.255
1991		235	70	0.298
1992		266	49	0.184
1993	Juvenile	150	48	0.320
1994		134	52	0.388
1995	Yearling	175	56	0.320
Total		1471	390	0.265

Table 5. Age-specific natality of branded females sighted at San Miguel Island, California, June-August 1996. All females sighted with pups were sighted at San Miguel Island.

Age	Number sighted	Number sighted with pups	Proportion sighted with pups
9	44	25	0.568
8	27	14	0.519
7	41	15	0.366
6	76	31	0.408
5	56	21	0.375
4	57	0	0.000
Total	301	106	0.352

Table 6. Survival rate estimates (SE in parenthesis) of female sea lions. Pup survival is for a pup of average weight from time of branding (~ October) to July 1 of following year.

	Pup	Yearling	2+ year old
Non-El Niño	0.86 (0.04)	0.83 (0.05)	0.95 (0.01)
El Niño (1992-93)	0.55 (0.05)	0.83 (0.05)	0.95 (0.01)

Table 7. Survival rate estimates (SE in parenthesis) of male sea lions. Pup survival is for a pup of average weight from time of branding (~ October) to July 1 of following year.

	Pup	Yearling	2+ year old
Non-El Niño	0.90 (0.06)	0.75 (0.05)	0.87 (0.02)
El Niño (1992)	0.80 (0.07)	0.75 (0.05)	0.87 (0.02)

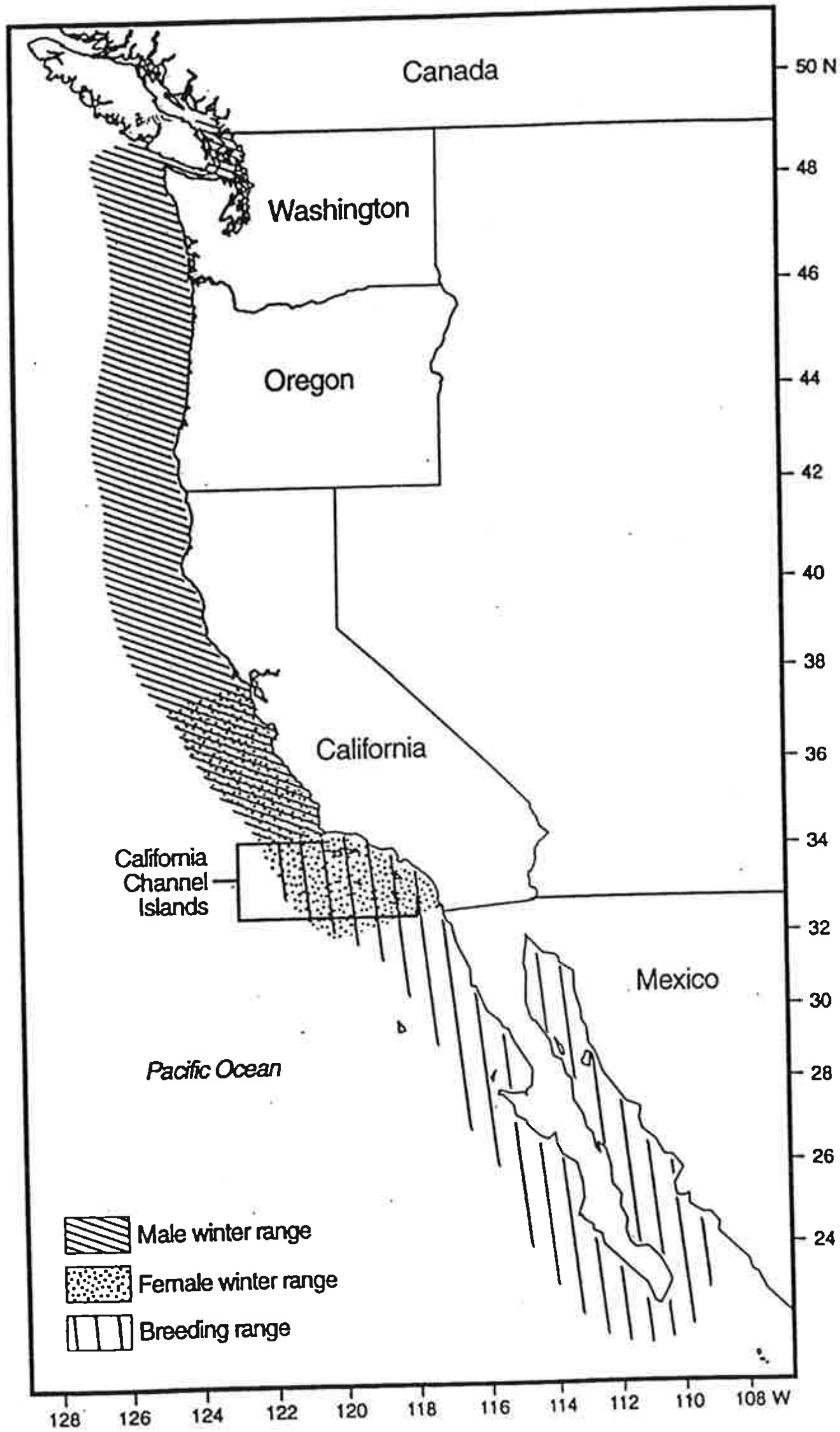

Figure 1. Breeding and migratory ranges of California sea lions.

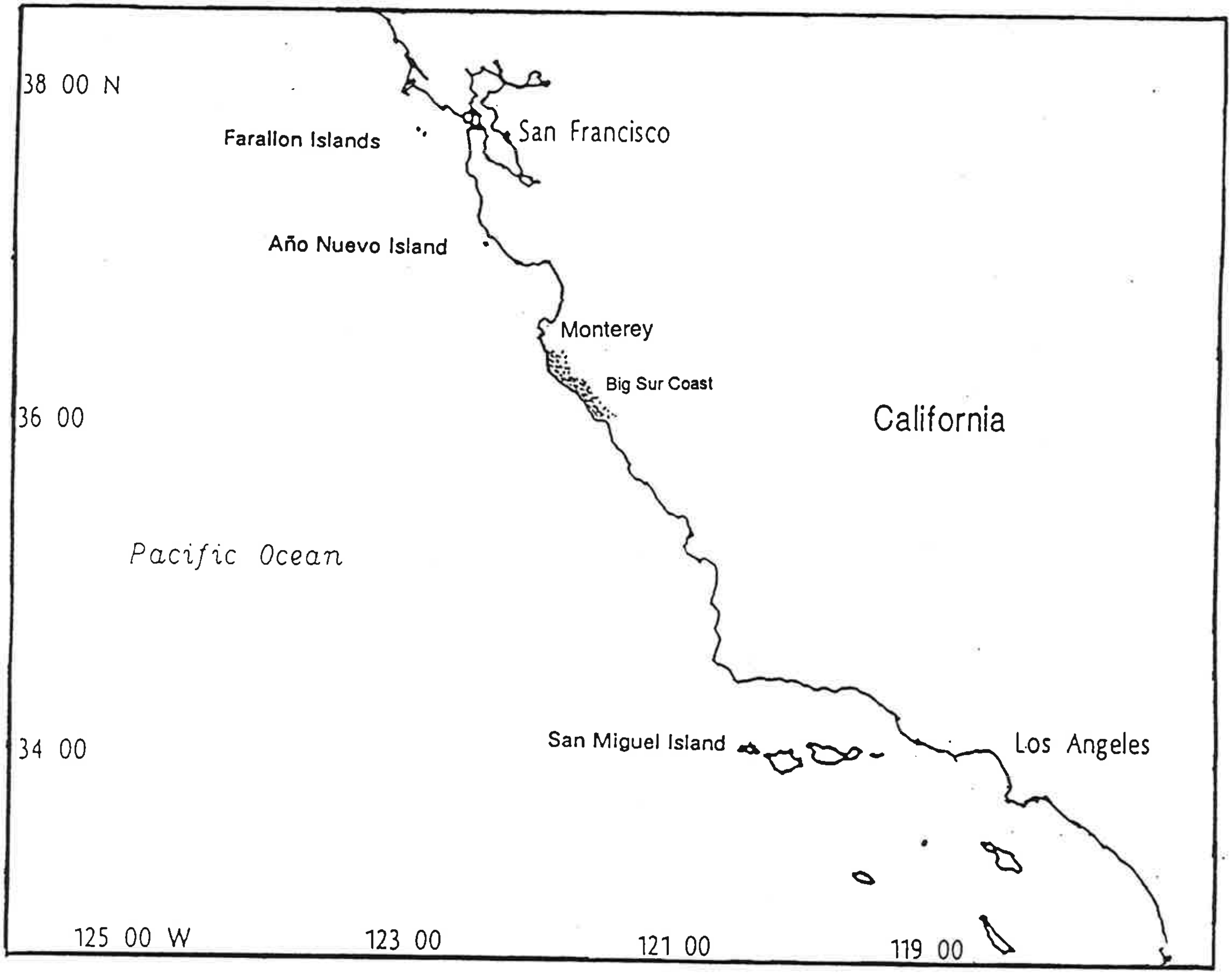

Figure 2. Study sites along the central California coast for observations of California sea lions, June-August, 1996.

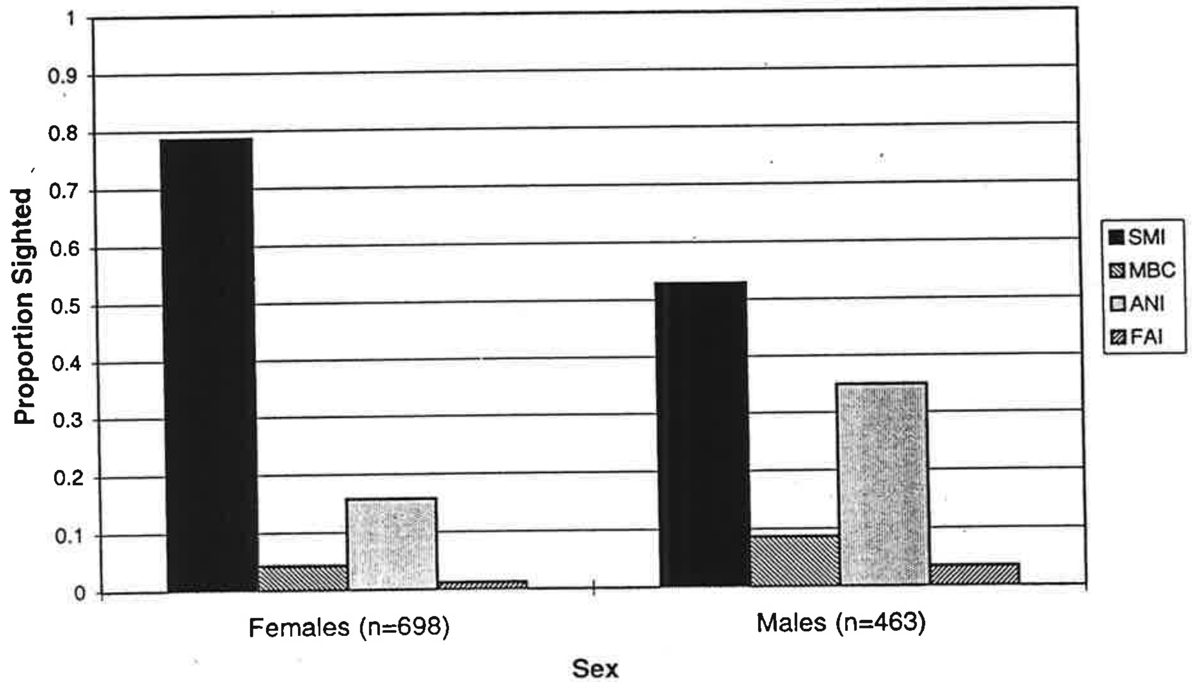

Figure 3. Distribution of sightings of branded female and male California sea lions among four study areas along the central California coast, June-July 1996. Area codes: SMI = San Miguel Island, MBC = Monterey Bay Coast, ANI = Año Nuevo Island, and FAI = Farallon Islands.

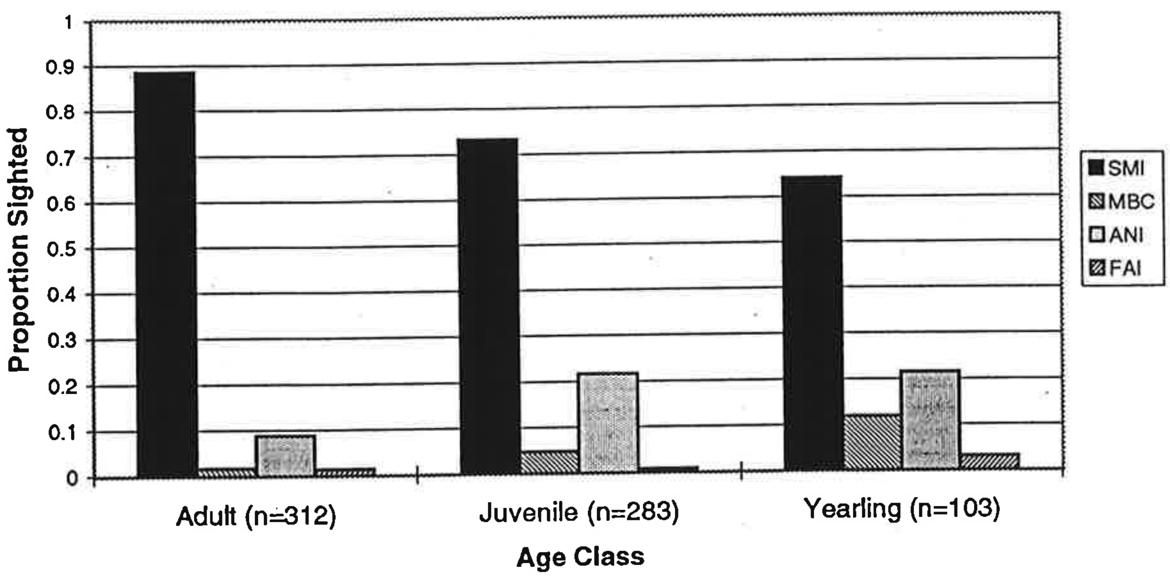

Figure 4. Age class distribution of sightings of branded female California sea lions for four study areas along the central California coast, June-July 1996. Area codes: SMI = San Miguel Island, MBC = Monterey Bay Coast, ANI = Año Nuevo Island, and FAI = Farallon Islands.

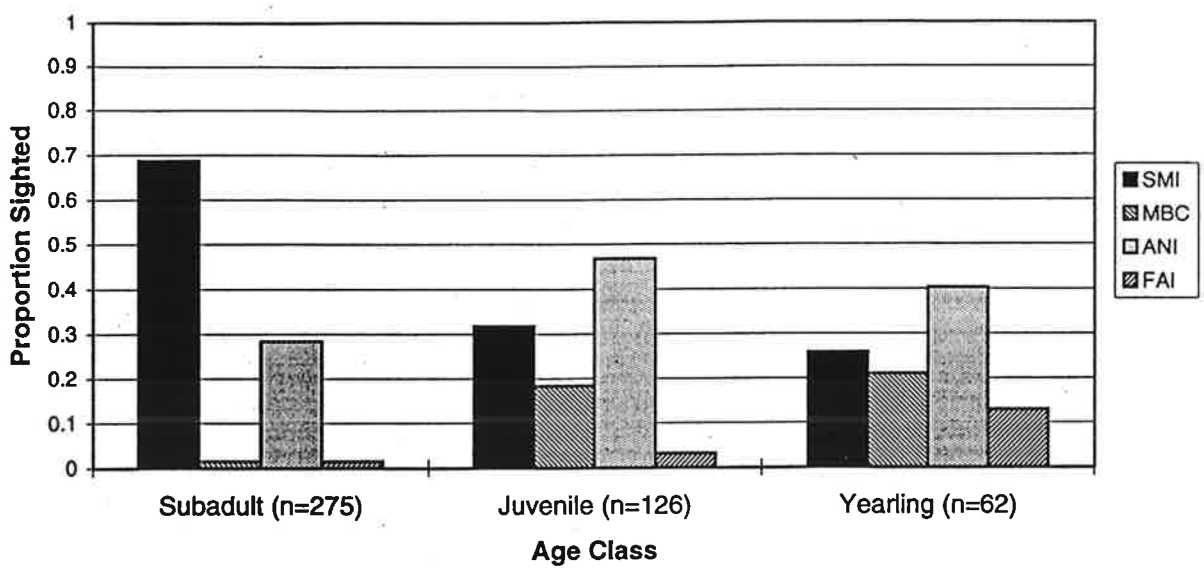

Figure 5. Age class distribution of sightings of branded male California sea lions for four study areas along the central California coast, June-July 1996. Area codes: SMI = San Miguel Island, MBC = Monterey Bay Coast, ANI = Año Nuevo Island, and FAI = Farallon Islands.

DALL'S PORPOISE DIVING BEHAVIOR AND REACTIONS TO TAGGING ATTEMPTS USING A REMOTELY DEPLOYED SUCTION-CUP TAG, AUGUST 1996

Robin W. Baird[1] and M. Bradley Hanson[2]

[1] Biology Department, Dalhousie University
Halifax, Nova Scotia, B3H 4J1, Canada
and
Marine Mammal Research Group
Box 6244
Victoria, British Columbia, V8P 5L5, Canada

[2] National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington 98115

Abstract

In August 1996, we were able to consistently locate Dall's porpoises (*Phocoenoides dalli*) in the transboundary waters between Washington State and British Columbia and approach animals for application of remotely deployed suction-cup attached time-depth recorder/VHF radio tags. Tagging activities were undertaken while porpoises were bow-riding on a small vessel. Fifteen tagging attempts were made, 13 of which resulted in tag contact with a porpoise. No reactions were observed for the two misses, nor for 2 of the 13 hits. Of the 11 cases when tag reactions were observed, porpoises returned to continue bowriding almost immediately in 7 cases, suggesting no long-term effect. Short-term reactions observed included a flinch (9 of 13 hits), tailslap (1 of 13 hits) and high speed swimming away from the vessel (4 of 13 hits), with some hits resulting in more than one type of reaction. Three of 13 hits resulted in successful tag attachment. One tag remained attached for 41 minutes, providing the first diving behavior data for this species. Rates of descent and ascent, as well as swimming velocity, were relatively high only for the first 6-8 minutes after tag attachment, suggesting a reaction to tagging that lasted approximately 8 minutes. The individual made 12 dives below 4 m in depth, with a maximum dive depth of 94 m (2.78 minute dive duration). Over 50% of the animal's time was spent in the top 10 m of the water column.

Introduction

Dall's porpoise (*Phocoenoides dalli*) appear to be numerous in the transboundary waters of British Columbia and Washington State (Baird and Guenther 1994), and seem to regularly approach vessels to bow-ride. As a prerequisite to capturing Dall's porpoises in FY 97 for tag attachment, a primary objective was to identify areas in the inland waters of Washington where this species could be consistently found and their approachability evaluated.

Collecting information on this species' swimming velocity, surfacing intervals, and dive depth was also considered important for the design and construction of the tag attachment, as well as for the programming of satellite tag sampling and transmission protocols. Although virtually nothing is known of the biology of this species in this area, Dall's porpoise are generally thought to be a deep-diving species. Such perceptions are based on several factors: 1) off-shore distribution over deep water, 2) occurrence of deep-water fish in stomach contents, 3) more massive skeletal musculature than other small cetaceans, 4) high blood-oxygen content, and 5) a relatively higher heart weight than other species (Ridgway 1966, Morejohn 1979, review in Jefferson 1988). They are also considered one of the fastest moving cetaceans. Leatherwood and Reeves (1986) suggested that Dall's porpoise might reach short-term burst speeds of up to 55 km/h (15.3 m/sec), although the maximum speed actually measured for this species by Law and Blake (1994) was 6.0 m/sec.

Time-depth recorders (TDRs) have been used with several species of small cetaceans to study habitat use and sub-surface behavior (e.g., Martin and Smith 1992, Scott et al. 1993, Baird 1994, Martin et al. 1994, Westgate et al. 1995, Davis et al. 1996). The incorporation of time-depth recorders into radio tags allows for detailed collection of data on sub-surface activities, specifically depth of dives, dive "shape" or profile, and rates of ascent and descent. On small cetaceans, such tags have been deployed either by using captured or stranded animals and surgically attaching tags, or by remotely attaching tags to free-ranging animals using suction-cups. Capture operations can be both difficult and expensive, and they run a risk of injuring or killing animals. Deploying tags by remote methods can also be difficult. Crossbow deployed suction-cup tags often bounce off, and the relatively large size of these tags results in very short range for firing them. Deployments by pole have a very limited range and are essentially limited to species that bow-ride, or to larger, slower moving species that can be closely approached by boats. On small cetaceans, remotely-deployed suction-cup tags have only been applied to killer whales (*Orcinus orca*), belugas (*Delphinapterus leucas*), Hector's dolphins (*Cephalorhynchus hectori*) and bottlenose dolphins (*Tursiops* sp.) (Baird 1994, Stone et al. 1994, Lerczak 1995, Schneider et al. 1996). One of these species, the bottlenose dolphin, seems to react strongly to these tags (Schneider et al. 1996), so much so that Schneider et al. (1996) concluded that this form of tagging was unfeasible (at least with the population they worked with in Doubtful Sound, New Zealand).

We were interested in applying suction-cup TDR tags to Dall's porpoise for two main reasons: 1) To record the reactions of Dall's porpoise to remotely deployed suction-cup tags in order to evaluate the feasibility of hoop-netting this species; and 2), if successful, to learn about the diving behavior of Dall's porpoise.

Methods

Tagging activities were based out of Victoria, British Columbia, and were undertaken in both Canadian and U.S. waters (primarily Haro Strait, but also Juan de Fuca Strait). The tag used was a modified version of one designed by J. Goodyear, which has been previously used with humpback (*Megaptera novaeangliae*), northern right (*Eubalaena glacialis*), fin (*Balaenoptera physalus*) and minke (*Balaenoptera acutorostrata*) whales (Goodyear 1981, 1989, pers. comm.), as well as killer whales (Baird 1994) and bottlenose dolphins (Schneider et al. 1996). The tag used has also subsequently been deployed on a killer whale (R. Baird, unpublished data) and a northern bottlenose whale (*Hyperoodon ampullatus*; S. Hooker and R. Baird, unpublished data). The tag (total weight of about 340 gm) was composed of a 7.5 cm diameter black rubber suction-cup (available from Canadian Tire - used for automobile roof racks and removing dents from automobile fenders) attached with flexible plastic tubing to an oval tag body. The flexible tubing allowed for some swivelling of the tag body on the cup. The tag body, constructed of syntactic foam (H-34, Billings Industries, Falmouth, MA; 1700 m maximum depth capacity), and covered with a thin layer of plastic (Plasti Dip, PDI, Inc, Circle Pines, MN), contained a Wildlife Computers Mk6 TDR (500 m depth data collection capacity, 2 m depth resolution), and a VHF transmitter (Model Dart-4, Telonics, Mesa, AZ; 12 mw power output, 70 pulses/minute, 164 MHZ) attached to a 3V lithium battery and with a 44 cm custom built wire antennae. The tag was designed to float upright with the antennae clear of the water's surface, after detaching from an animal. A magnesium release system was incorporated into the suction-cup, limiting the maximum duration the tag would remain attached. The release mechanism involved a stainless steel tube, threaded on the outside, fitted through the body of the suction cup, and a threaded magnesium cap (0.01" wall thickness) which was screwed on to the end of the tube. A rubber disk, coated with silicone grease (Dow Corning 111 valve lubricant and sealant), was inserted into the magnesium cap, to create a seal against the end of the stainless steel tube. The inner surface of the suction-cup was also coated with this grease prior to tagging attempts. The TDR had three sensors which were activated, a pressure (depth) sensor, a velocity sensor, and a salt-water switch. The accuracy of the pressure sensor was previously tested by subjecting the TDR to known pressures using a pressure chamber, and comparing the depth readings measured by the TDR. The sampling rates for the sensors were set at once per second. The velocity sensor on this tag calculates velocity based on the number of turns of a turbine, such that with a 1 sec sampling rate the resolution of the sensor is 0.1 m/sec (M. Braun, Wildlife Computers, pers. comm.).

When weather conditions permitted, we surveyed the study area using a 7 m boat looking for Dall's porpoise. When porpoise were sighted, the vessel was slowed and maneuvered in the direction of the animals. Tagging attempts were made while seated on the bow of the vessel, with the tag attached to the end of an extension pole (length ranging from approximately 2 to 4 m). When porpoises approached the vessel to bowride, the pole (with tag attached) was held over the front of the boat. When a porpoise surfaced directly in front of or immediately beside the research vessel, an attempt to tag could be made by bringing the suction-cup quickly in contact with the dorsal surface of the porpoise between the blow hole and the dorsal fin. The behavior before (always bowriding) and after tagging attempts was recorded. Reasons why approaches were discontinued (e.g., porpoises lost interest, other boats approached) were also recorded on an ad hoc basis.

Results and Discussion

Weather conditions permitted field work on 7 of 10 days in August 1996. Dall's porpoise groups were encountered and approached the vessel each day, most consistently in northern Haro Strait. Thirty-six groups were encountered during this period, of which up to 10 groups were encountered per day. Twenty-two of the groups that were encountered approached the vessel (60%), but the number that approached on a given day was variable. There were a total of 15 tagging attempts (of which 13 were hits). Several conditions were required before tagging attempts could be made. These included: 1) relatively calm seas (Beaufort 0 or 1), in order to see the animals prior to surfacing and allow for proper pole placement - extremely rapid movement of the pole would sometimes result in dislodging of the tag from the pole end; thus, some prior warning of where a particular porpoise was going to surface was necessary for an attempt; 2) suitable light conditions - seeing animals below the surface was facilitated by having the sun behind the vessel and fairly high in the sky, again allowing for proper placement of the pole prior to an attempt; 3) relatively slow travel speeds - if porpoises were traveling quickly, surfacing occurred too fast for tagging attempts to be made; and 4) no other boats within the immediate vicinity. The area where tagging operations were taking place is a region of high vessel traffic, including commercial whale watching operations which focus some of their attention on Dall's porpoise. To minimize any negative public reactions resulting from observations of tagging activities (without being able to explain the nature and goals of the project and the potential reactions of the animals), we discontinued tagging attempts when other vessels approached within a few hundred meters (this occurred quite frequently).

Cases where Dall's porpoise reacted to tagging attempts are summarized in Table 1. Not all attempts resulted in a visible reaction. No reaction was observed in either case when the tag did not make contact with a porpoise, and 2 of 13 hits resulted in no visible reaction by the animal. Three other "types" of immediate reactions were noted. These included a flinch (9 of 13 hits), a tailslap (1 of 13 hits), and high speed swimming away from the vessel (4 of 13 hits) (though on some occasions two of these reactions were exhibited by the same animal). For the 11 cases where an immediate reaction was seen, individuals returned to the boat to bowride (or did not discontinue bowriding) in 7 cases (suggesting no long-term impact, despite the short-term reaction). Three of the 13 hits were successful in attaching the tag, though only one remained attached for an extended period (41 minutes). The short durations of the other two attachments (less than 2 minutes each) may have resulted from an air leak in the suction-cup (discovered later). In all three cases where the tag stuck, the animals swam quickly away from the boat (though the boat was also stopped at this point to try to track the tagged animal).

Monitoring of a VHF receiver was undertaken for the entire period when an individual was tagged. We were able to obtain the first data on diving behavior of this species - for one individual tagged for 41 minutes on 9 August 1996, in the U.S. waters of northern Haro Strait. The tag was attached at 1203 hrs (local time), and came off the animal at 1244 hrs. For the one individual tagged for 41 minutes, strong VHF signals were received on 5 occasions during the first few minutes after the tag was attached, and two signals were received about 33 minutes after tag attachment. The time that the tag detached from the animal was clearly indicated by the reception of strong, continuous VHF signals (as the tag floated at the water's surface with the antennae clear of the water). That so few signals were received during the majority of the period while the tag was attached is probably due to the tag sliding down along the side of the body of the animal (as has frequently been recorded with suction-cup tags on killer whales; R. Baird unpublished data). The animal was not visually re-sighted during the period when the tag was attached, though no effort was made to follow the individual. The tag was recovered within 2 km of where the animal was originally tagged - evidence that the animal stayed in the general vicinity of where it was tagged. The sex of this individual was not known. Body size was estimated in the field to be about that of a sub-adult (approximately 50 kg), thus relative tag weight was estimated to be about 0.7 % of body weight.

Information on the animal's reaction to tagging was apparent in the TDR data. Figure 1 shows depth information over the entire tagging period. During the first few minutes after the tag was attached the animal remained close to the water's surface (within the top 2-6 m) before beginning a series of deeper dives. Examining the rates of descent and ascent during the first few deeper dives (Table 2) suggests that the animal was diving faster during the first few minutes than for the remainder of the tag attachment. Velocity readings were also highest during the first 8 minutes of the tag attachment (Fig. 2). These velocity readings, however, are not particularly high for this species. Law and Blake (1994) measured swimming velocity of free-swimming Dall's porpoise using video recordings of surfacing animals, obtaining velocities of 3.4 to 6.0 m/sec (mean of 4.3 m/sec) for "rooster-tailing" (i.e., fast swimming) animals, and 1.6 to 2.1 m/sec (mean = 1.8 m/sec) for "slow rolling" animals. Readings from our tagged animal were only within the range which Law and Blake (1994) recorded for rooster-tailing animals during the first 4 minutes after tagging. As noted above, however, accurate calibration of the velocity meter is not possible, thus readings given could differ from actual speed of the animal.

A closer examination of the velocity data in relation to the porpoise's position in the water column (i.e., near the surface versus at depth) sheds further light on the duration of disturbance. Swimming speed generally decreased with an increase in depth during the first 6 minutes (from 1206 to 1212 hrs) after the animal began to dive below 4 m in depth (regression, $p < 0.001$, $r^2=0.456$, df = 357). We suggest this relationship may reflect the individual's avoidance of the surface waters as a reaction to the tagging attempt. No such relationship was apparent for the 6 minute period after 1212 hrs (regression, $p = 0.717$), nor for the remainder of the tag attachment. Combined with the decrease in the rates of ascent and descent after the first few minutes, this change in behavior over time leads us to believe the animal was no longer "disturbed" after the first 6 or 8 minutes of tag attachment.

This individual made 12 dives below 4 m in depth (the minimum depth to be considered a "dive", given the depth resolution of the TDR)(Table 2). The bottom depth in the area where the animal was tagged generally exceeded 200 m, yet the maximum dive depth was 94 m. As noted previously, a variety of other information (feeding habits, physiology and morphology) suggests that Dall's porpoise can dive quite deeply; we suspect the relatively shallow dives of our tagged individual are an artifact of the short duration of our tag attachment. Over the 41-minute period, the tagged animal spent over 50% of its time in the top 10 m of the water column (Fig. 3). Such information, on the proportion of time the animal spends in the top few meters of the water column, may be of interest to investigators undertaking aerial surveys for this species.

In conclusion, Dall's porpoise are expected to be consistently encountered in the study area in sufficient numbers that readily approach close enough to the vessel to potentially allow capture by breakaway hoop-net. Dall's porpoises reacted much less to tagging attempts and tag attachment than did bottlenose dolphins, using virtually the same tag and methods. Dive intervals should allow for sufficient surface time during a satellite pass to get good quality locations. Dive depths do not indicate the need for extraordinarily reinforcement of the transmitter housing. Velocity data will be important in estimating loading on dorsal fin tissue in future bioengineering studies.

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Table 1. Tagging attempts where a reaction was observed. Each line represents a different tagging attempt.

Date	No. Animals[1] Responding	Behavior During Attempt[2]	Behavior After Attempt	Tag Attachment (yes/no)
8 August	1	flinch	bowriding	no
8 August	1	flinch	bowriding	no
9 August	1	flinch	bowriding	no
9 August	1	flinch	bowriding	no
9 August	2	tailslap by 1, high speed swimming away by both	high speed swim away	yes (41 min)
10 August	4	flinch by 1, high speed swimming away by all	social	no
10 August	1	high speed swimming away	high speed swim away	yes
10 August	4	flinch by 1, high speed swim away by all	high speed swim away	yes
12 August	1	flinch	bowriding	no
12 August	1	flinch	bowriding	no
15 August	1	flinch	bowriding	no

[1] Only one tagging attempt was made in each case - when the number of individuals given is greater than 1, reactions were also observed for nearby (always less than 5 m) individuals.
[2] Behavior before tagging attempts in all cases was bowriding.

Table 2. Characteristics for all dives at least 4 m in depth[1].

Dive No.	Start Time of Dive	Maximum Depth (m)	Duration (min)	Bottom Time[2] (min)	Average Rate of Descent[3] (m/sec)	Average Rate of Ascent[3] (m/sec)
1	12:06:04	14	0.2	0.08	3.43	3.43
2	12:06:39	30	0.45	0.13	3.47	2.26
3	12:07:21	26	0.75	0.1	1.45	1.07
4	12:08:19	28	0.57	0.15	2.09	1.78
5	12:09:18	60	2.12	0.73	1.17	1.35
6	12:12:02	94	2.78	0.75	1.09	1.65
7	12:15:29	20	1.2	0.55	1.44	0.68
8	12:17:07	46	2.18	1	0.94	1.4
9	12:19:57	64	2.15	0.4	0.85	1.42
10	12:22:50	44	1.4	0.35	1.07	1.38
11	12:24:45	50	2.28	0.48	0.7	0.97
12	12:27:38	36	1.97	0.52	0.69	0.79
13	12:30:14	24	1.82	0.92	0.98	0.7
14	12:32:55	8	0.72	0.53	1.78	1.23
15	12:34:41	4	0.22	0.2	-	-
16	12:38:32	10	0.7	0.02	0.61	0.39
17	12:40:31	10	0.47	0.12	1.05	0.87
Mean (SD)		33.4 (23.9)	1.29 (0.84)	0.41 (0.31)	1.43 (0.88)	1.34 (0.73)

[1] With a 2 m depth resolution of the TDR, 4 m was the minimum depth that could be considered a "dive".

[2] Bottom Time was calculated as the amount of time spent below 85% of the maximum depth.

[3] Average rates of descent and ascent calculated using depth versus time data, not using the velocity sensor.

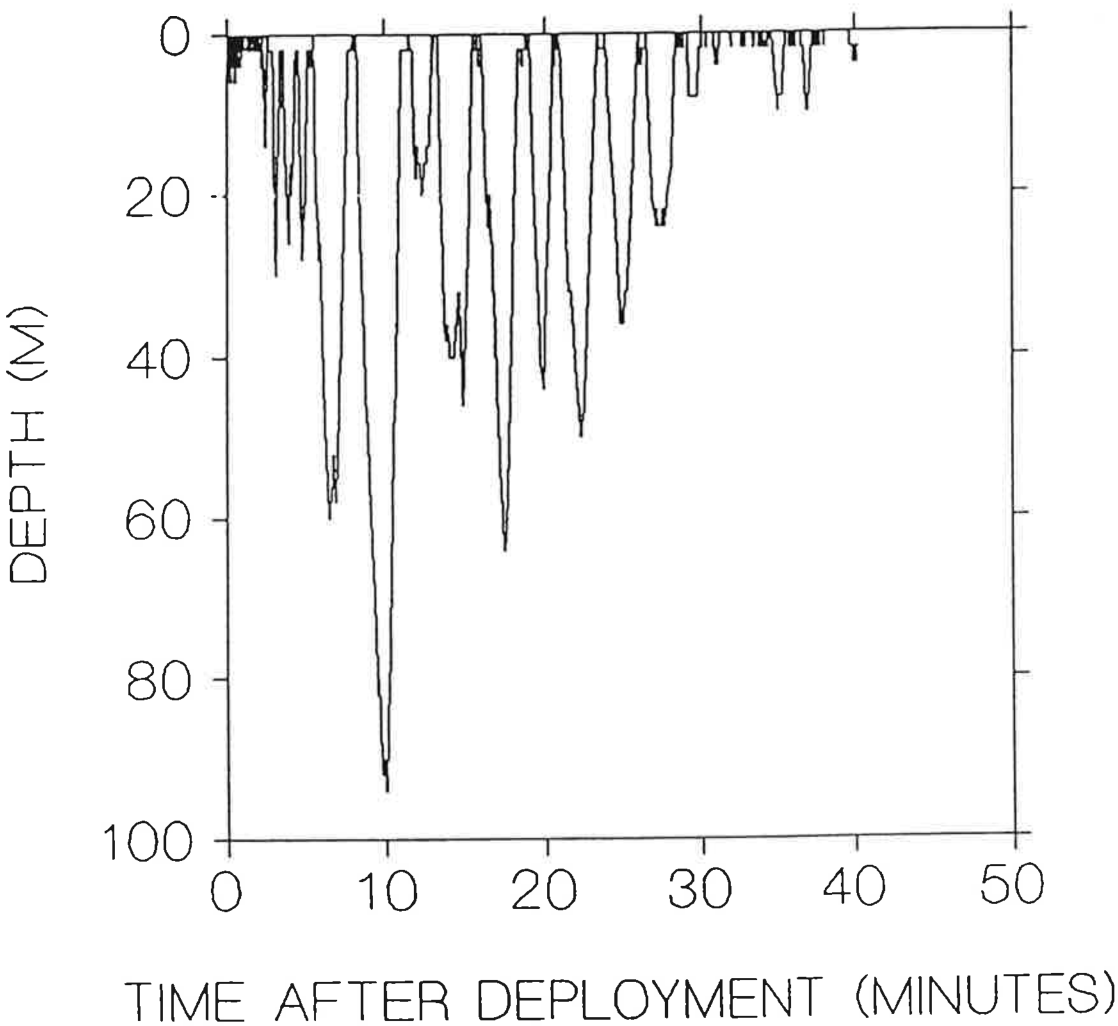

Figure 1. Profile of porpoise depth over the 41 minute tag attachment.

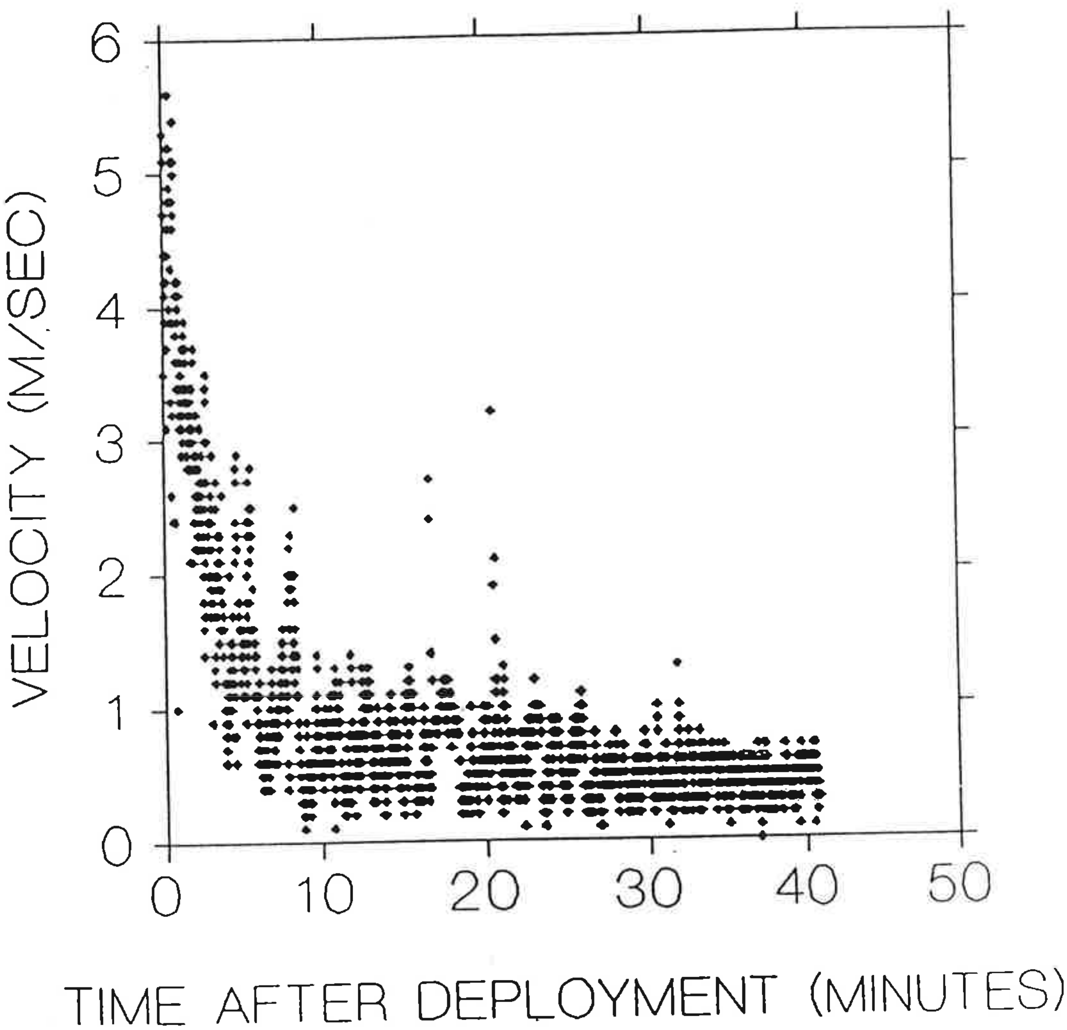

Figure 2. Profile of velocity (m/sec) over the 41 minute tag attachment.

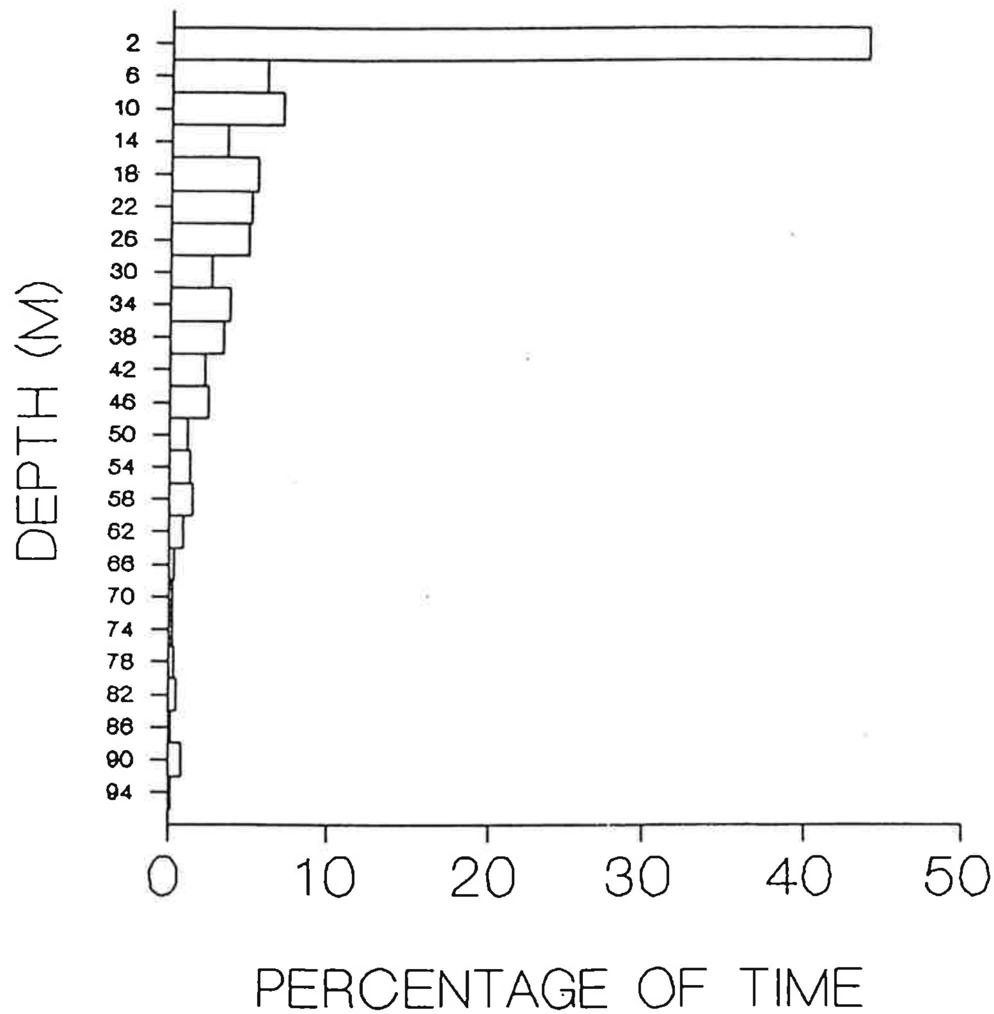

Figure 3. Proportion of time spent at different depths. Each value on the Y-axis represents the mid-point of each depth category (e.g., 2 = depths from 0-4m, 6 = depths from 4-8m, etc.).

AN ASSESSMENT OF GRAY WHALE COUNTS MADE BY SHORE-BASED OBSERVERS

David J. Rugh, Rod C. Hobbs, Jim A. Lerczak,
Lisa S. Baraff, Janice M. Waite, Cynthia D'Vincent, P. Scott Hill, and Marcia M. Muto

National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington 98115

Abstract

Counts of gray whales (*Eschrichtius robustus*) during their southbound migration have been conducted from shore-based stations in central California for most years since 1967. Studies of the survey protocol have provided information on observer biases and estimates of whales missed within the viewing area. This study examined pod size estimates relative to records of whale groups tracked through the viewing area. During the survey period, 7-23 January 1997, 34 pairs of concurrent, independent standard watches, plus 2 watches by single observers, were conducted for a total of 63 hrs of standard counting effort in useable conditions. Meanwhile, teams of observers at the same site made 133 track records of 100 groups of whales. Of these tracks, 95 were considered excellent to fair records (track qualities of 1 to 3), and the remaining 38 records (track qualities 4 and 5) were compromised by visibility, high densities of whale pods in the area, or other factors that made it difficult to follow the focal pod. Paired teams of observers made independent, concurrent tracks of 34 whale groups. These showed fairly good agreement in judgments of track quality (subjectively rated from 1 to 5); in only 5 cases were track quality discrepancies >1. Also, agreement in pod sizes occurred in 65% of the cases, with discrepancies of only 1 whale in 10 of the cases, and discrepancies >1 in 2 cases. There were 68 groups of whales recorded both by one or two teams of trackers and by one or both observers on the standard watch. This resulted in 144 comparisons of pod size estimates. Pod size estimates were the same in 45% of the cases; 12% of the pods were overestimated; 43% were underestimated. Observers on the standard watch tend to underestimate the number of whales in a group: pods recorded as size 1 should be corrected by +0.8, pods of 2 by +0.9, pods of 3 by +1.5, and pods >3 are not significantly over- or underestimated on average.

Introduction

Gray whales (*Eschrichtius robustus*) in the eastern Pacific Ocean have made a remarkable recovery since the 19th century, when they were nearly exterminated by commercial whaling. This recovery has been documented by abundance estimates made from shore-based counts in California since 1967 (Buckland and Breiwick, in press). In 1986 the standardized counting procedure was evaluated for repeatability through a 6-day test with paired, independent observers

(Rugh et al. 1990), a test which was applied throughout the 1987/88 census (Rugh et al. 1993). During each census since then, paired, independent counts of whales have been made for some or all of the daily watches as a part of the abundance estimations (Hobbs et al. in press). This has provided a documentation of the degree of consistency between observer's sighting records, and it has led to a modification of abundance calculations by correcting for whales missed within the viewing area during a watch.

After nearly a decade of applying the paired, independent observer tests, it is evident that this is a valuable tool in evaluating observers' sighting records. However, there are some limitations to this technique; for instance, discrepancies in pod size estimates and linkages between sightings have been treated as an error of undercounting on the part of the observer with the fewer sightings. What has been needed is an efficient (large sample size per cost) technique to study sighting records and related variables used to calculate correction factors, in part, to give a better assessment of the error range in the census data, but also to provide improved parameterization of elements (sighting time, distance, and pod size) used in the matching algorithm. The factors of the gray whale abundance estimate with the greatest uncertainties and potentially the greatest unknown biases are the pod size correction factor, links made between sightings by each observer, and the matching algorithm (matching sightings between observers). All of these involve knowledge of how an observer identifies and interprets the visual cues from a pod of whales passing the study site. The gray whale survey design and analysis are based on some basic assumptions: that gray whales travel in fairly discrete pods that remain cohesive as they pass through the observers' visual field; the pods have a typical travel speed (6 km/hr; Swartz et al. 1987), migration path (parallel to the coast), and surfacing behavior pattern (average surfacing intervals of 1.3 min and long dives of 3.1 min; Swartz et al. 1987); and that no sighting data are recorded in the absence of whales ("false positives"). These assumptions are fundamental to the way each observer links an initial sighting of a whale group to the sighting that occurs closest to the standard viewing line (241°). These assumptions must also be met to accurately compare concurrent sighting records through the matching algorithm. In particular, assumptions of pod integrity must be met - at least for the several minutes it takes a pod to travel through the viewing area. Accurate pod size estimation is an integral component of the survey because it is more efficient both for data recording and statistical analysis to count pods and estimate pod size than to record individual whales. Available tracking data and observer experience have indicated that, in the majority of circumstances, gray whale pods are sufficiently cohesive and behave in a manner predictable enough to support this approach. What remains is to determine the range of deviation from the typical behavior and to quantify any biases that may result from errors in linking sightings within each record, matching sightings between records, and pod size estimations.

To address these issues, we conducted a study during the gray whale southbound migration in January 1997 at the observation site at Granite Canyon. The objectives were to examine how gray whale pods moved through the survey viewing field and to compare these observations to data recorded for the respective pods during the standard watch. More specifically, the objectives were to: 1) develop and test a reliable method for tracking whale groups; 2) measure the precision of time and location data recorded during the standard watch; and 3) measure the precision of pod size estimates made during the standard watch. This test assumes that teams of observers working in pairs can reliably follow and record sighting locations and sizes of pods of whales as they migrate through the primary viewing field. These tracking records, when compared to the standard counting records, may then be used to calibrate pod size estimates, inter-sighting linkages, and the inter-observer matching algorithm.

Methods

From 7 to 23 January 1997, NMML conducted a study of the research protocol used to count gray whales migrating past the Granite Canyon research station. The four observation sheds erected on 7 January 1997 were 87 m south and 0.87 m higher than the site used in previous years (1974-96) due to contaminated soils at the old site. This change was not considered to be significant relative to the limits of precision in the binoculars' reticles and compasses. Sighting records collected on 7 and 8 January were considered practice and training periods. From 9 to 21 January, observations were conducted throughout most daylight hours. Data were entered into a computer and were quality-checked before the next day's effort began. On 22 January, a rain storm precluded any effective watch effort. A final watch was conducted on 23 January, and the sheds were dismantled.

In this study of counting protocol, 7 of the 8 observers had conducted shore-based counts of gray whales in the past, including one observer who conducted counts from 1975 to 1985 and another from 1977 to 1996. Most observers rotated between the counting and tracking efforts daily. Observation rotations balanced the pairings between observers on the independent, standard counts and balanced the use of the two sheds (minimizing minor potential biases).

Two independent, concurrent, standard counting records (referred to here as standard watches) were conducted each day, weather allowing, for approximately 8 hrs, with emphasis on maintaining the protocol used since 1985 (Rugh et al. 1993). This included the use of reticled binoculars with magnetic compasses to record the vertical and horizontal components of the location of one or two sighting positions for each whale group. A table with reticles and bearings provided an estimated time and location that whales, traveling at the expected speed (6 km/hr) and direction (parallel to the coast), would arrive at the 241° standard viewing line.

While the standard counts were being conducted, one or two teams of trackers selected whale pods well to the north of the 241° line and tracked them as they migrated south through the viewing area. Pod selection was kept confidential from the observers on the standard watch, and it was somewhat randomized to avoid potential bias towards selecting large pods in the middle of the search area. The selection process was kept efficient by using a regime of searching the area for up to 5 minutes and selecting a focal pod based on the timing of the sightings. Each focal pod was then tracked constantly by one observer with binoculars while the other recorded information and watched opportunistically. When two teams of trackers were available, they conducted concurrent tracks of the same focal pods. Operating from separate sheds, observers identified focal pods by communicating with wireless headsets. Communication stopped when pods reached prescribed boundaries (270°, 260°, or 240°), after which each tracking team followed the respective pods independently. The goal was to collect 10 concurrent tracks in each of the three prescribed tracking boundaries.

Sightings were recorded according to time (to the second), reticle (to the nearest 0.1 reticle), horizontal angle (to the nearest degree), pod size, and direction headed if not southbound. Time, reticle, and angle were precisely recorded to keep data as comparable as possible to the standard watch. When there was confusion about a time entry, it was considered tentative (T) if the error was within 10-60 sec; it was considered unknown (U) if the error was >60 sec. Whale groups were tracked until they were well south of the viewing window used by the observers on the standard watch (e.g., 230°), with a typical track lasting approximately a half hour.

A track quality code (TQ) was established to record the relative degree of confusion a tracker may have had between the focal pod and other nearby pods. This was a combination of subjective evaluations: visibility of the whale pod; density of whale pods in the sighting area; behavior of the pod; distractions incurred during the tracking event; etc. TQ reflected how confident the tracker was that the focal pod was consistently followed: TQ1 = the focal pod was clearly distinct; TQ2 = all but a few surfacings were distinct; TQ3 = there may have been some surfacings that were confused between whale groups; TQ4 = it is uncertain whether the track record was from the focal pod only or if it included one other pod; TQ5 = the focal pod could have been confused among several other pods. In the analysis, only when TQ was less than 4 were the data used for comparing pod size estimates.

Observers reviewed their data immediately after each tracking event, or as soon as possible, to create the best possible written record. Any discrepancies that occurred between multiple observers were resolved by consensus during the data review.

Results

During 14 days between 7 and 23 January 1997, there were 34 pairs of concurrent, independent standard watches, plus 2 watches by single observers. Most standard watches were 3 hrs each; 7 were only 1.5 hrs to maximize efficiency in data collection while limiting the field time to 8 hrs/day. A total of 63 hrs of standard watch effort was collected in fair or better sighting conditions.

A total of 133 track records of 100 groups of whales were collected. Figure 1 shows tracks collected from the team in the south shed while doing concurrent efforts with the team in the north shed. Of the 133 tracks, 95 (71%) were considered excellent to fair records (TQ<4), and the remaining 38 records (TQ≥4) were compromised by visibility, high densities of whale pods in the area, or other factors that made it difficult to follow the focal pod. When two teams of trackers followed the same group (n = 34), most of the judgments on track qualities were the same (59%) or different by only 1 increment (26%); in 5 cases (15%), discrepancies were greater than 1. The paired sampling did not show significant differences between track qualities recorded by the paired teams (two-tailed t test, p = 0.66).

Of the 34 concurrent track records, observers agreed on pod sizes 22 times (65%) and had discrepancies of only one whale 10 times (29%), while in 2 (6%) cases discrepancies were greater than 1 (5 vs. 7, and 3 vs. 6). Removing samples when at least one team considered the track quality compromised (TQ >3; n = 22) does not make a large change in the results: there were 15 (68%) times in which both teams agreed on pod size, 5 differences (23%) of only one whale, and 2 differences (9%) where discrepancies were >1. Put in another way, when track qualities were excellent (both teams recorded TQ=1), 9 out of 12 times (75%) they agreed on pod size; when the maximum TQ was 2, agreements were made 5 out of 7 times (71%); when the TQ was >2, agreements were made 8 out of 15 times (53%)(Table 1). Although the sample size does not allow for a rigorous comparison of observers (there were only 0 to 4 pair-wise comparisons, and 6 to 17 concurrent tracks were collected by each of the 7 observers), no one observer performed very differently from the others: pod size discrepancies occurred only 2-4 times per observer. When limiting analysis to focal pods with TQ<4, sample sizes were too small to compare tracking efforts between each of the prescribed zones (270°, 260°, and 240°; n = 5, 4, and 4, respectively).

There were 68 groups of whales recorded both by the trackers and by at least one observer on the standard watch; 32 tracked pods were not seen by an observer on the standard watch. Matches between the records were only included if track qualities were good (TQ<4), visibility was good (VIZ<5), and the matches were considered unequivocal. Using each combination of pod size estimates between the trackers (often two concurrent but independent teams) and the standard watch (usually two independent observers), there were 144 matched records. Preliminary analysis between the trackers and the standard watch indicates that there was a good comparison in pod size estimates (Table 2). Entries on the diagonal (45% of all matches) indicated that both trackers and observers on the standard watch made the same pod size estimates. In only 12% of the cases, observers on the standard watch overestimated pod size, and in 43% of the cases they underestimated. Table 3 presents the results in a format used by Reilly (1981). This shows that pods recorded as 1 on the standard watch were underestimated by 0.80 ($p<<0.001$), estimates of 2 should be corrected by 0.90 ($p<0.001$), estimates of 3 should be corrected by 1.5 whales ($p = 0.003$), and pods larger than 3 were not significantly under- or overestimated ($p = 0.366$).

Miscellaneous Marine Mammal Sightings

In addition to gray whales, several other species of marine mammals were seen. Sea otters (*Enhydra lutris*), California sea lions (*Zalophus californianus*), Steller sea lions (*Eumetopias jubatus*), and harbor seals (*Phoca vitulina*) were frequently seen but were not recorded. Over 150 common dolphins (*Delphinus delphis*) were observed on 14 January. Several killer whales (*Orcinus orca*; 2 males and 3+ females or subadult males) were seen on 11 January. For approximately 1.8 hrs they were very active 3-4 km northwest of the study area, porpoising, fluke-slapping, and breaching; then they surfaced slowly in a small area, joined by a large flock of gulls.

On 16 January, a pod of 7 or more gray whales headed toward shore in front of Granite Canyon. This pod was pursued by 15-20 Risso's dolphins (*Grampus griseus*) that approached so rapidly they were rooster-tailing across the surface. Most of the gray whale pod swam north close to shore in a tight group, but one young gray whale seemed to have been singled out. It swam to the north, close to shore, upside down with its chin out of the water for several seconds at a time. It frequently extended a tattered flipper and flukes above the water. The Risso's dolphins surrounded the gray whale, and then, about 5 minutes later, they swam slowly south, followed by the young gray whale more than 1 km behind.

Discussion

Our first objective, to develop and test a reliable method for tracking whales, was achieved with equivocal success. Although it proved difficult to follow a whale or group of whales through the viewing area, this process did provide an empirical record of apparent linkages between multiple sightings. Because the trackers worked from the same site as used during the standard watch, and because the tools (reticled binoculars) and observers (through rotations) were the same, the perspective of the whale groups was the same. This helped avoid problems of trying to identify which whales were seen by aerial teams during pod size calibration tests. Furthermore, the aerial calibration tends to draw attention to the area where the aircraft is circling and may bias upwards the amount of time observers watch pods in that area.

What gave a considerable advantage to the trackers over the observers on the standard watch was the open communication between two observers (one who was dedicated to searching only without having to look down to record) and the option to focus on one group at a time, staying with it for approximately a half hour. Independent, paired tracking teams served to test the repeatability of this effort. What is needed now is an independent test of the tracking method, such as an aerial operation in communication with the tracking team but not communicating with the observers on the standard watch. This study is currently proposed for the next counting season.

The second objective, measuring the precision of time and location data was based on the assumption that appropriate matches were made between the record in the standard watch and the record made by the tracking team. And it is assumed that the tracking team had relatively more precise data than that collected during the standard watch. Matches between these two records were examined manually during the field season and were later checked and then compared to a computerized matching algorithm. The combination of these efforts made it highly probable that all appropriate matches were found.

Precision in the tracking data was achieved through multiple sightings of a whale group, thus minimizing the probability of spurious records. Plotting the location data provided a degree of quality control. Open communication between the dedicated observer and the recorder in the tracking team allowed immediate infield data checks and made for more reliable recordings because, unlike the standard watch, the dedicated trackers did not need to look down to write.

The third objective, precision in group size estimates, was met in comparisons between the standard effort and the tracking records. These comparisons showed that small groups are underestimated but that larger groups are fairly accurately estimated. This may be a function of the demands placed on the observers doing the standard watch, when they must search for whales, make judgments on resightings, collect sighting data, and then look down to record sighting data. During particularly busy times, it is possible that observers on the standard watch made estimates of pod sizes from only one series of surfacings. Pod sizes were easily underestimated, but when an observer noticed that a group had 4 or more whales, the group might have been studied more intensely, resulting in the apparently more accurate counts (Table 3).

Cynthia D'Vincent conducted counts of whales from 1975 to 1985. This study in 1997 was her first experience with the procedures as modified since tests of the system were initiated in 1986 (Rugh et al. 1990). Although there has been an attempt to maintain the same survey protocol through the years, Cynthia described the current counting effort as being more oriented toward recording sighting locations and linking pods than efforts from 1975 to 1985 when there was more time available to follow each pod and fewer data entries were necessary. It is not known how much these changes in counting methods affect abundance estimates, but the increased data entries (both from writing location information and from higher whale densities) would probably result in underestimating the number of whales, muting rather than exaggerating the apparent population increase.

Results from this study of pod size estimates can be compared to similar efforts conducted with aircraft (Reilly 1981, Laake et al. 1994) and with thermal sensors (DeAngelis et al. 1997). An aircraft was used in 1978 (Reilly 1981) to establish pod sizes relative to estimates made by 12 shore-based observers. This resulted in 381 comparisons of pod size estimates (Table 4). It was established that pods recorded as having 2 or 3 each were accurate enough on average to not need corrections, while whales recorded as traveling alone or in pods of 4 or more should be corrected by +0.35 and +0.33, respectively.

Laake et al. (1994) also used aircraft to establish pod sizes, but their results, collected in 1993 and 1994 (n = 240), were different from Reilly's (1981): each pod size estimate needed corrections, and the size of the corrections diminished as the size of the estimates increased (Table 4), which is a pattern opposite to the results of the current study. But comparable to the current study, pod size estimates of 4 or more were not significantly different from the calibrated sizes.

Thermal sensor data, collected in 1995 and 1996, were based on 245 matches between pods studied on video tapes and pods recorded on the standard watch at the same time (Table 4). They found a 70% agreement in pod size estimates, well more than the 44% found by trackers in the current study. There were no significant differences between methods when observers on the standard watch recorded pods of 2 or 3 whales, but the thermal sensors found more whales in pods recorded as 1 (+0.36) or pods of 4 or more (+0.35). These results are nearly identical to those of Reilly (1981), but not the same as those collected in the current study or in Laake et al. (1994).

Conclusions made in this manuscript should be considered tentative because there is only a small number of comparisons between survey methods and there remain many aspects of the data that still need to be examined.

Acknowledgments

The National Marine Mammal Laboratory, NMFS, NOAA, provided support for this study with funds directed through NOAA's F/PR Marine Mammal Research Plan. Observers were Lisa Baraff, Cynthia D'Vincent, Scott Hill, Rod Hobbs, Jim Lerczak (9-20 Jan.), Marcia Muto (10-24 Jan.), David Rugh, and Janice Waite. Doug DeMaster provided administrative overview. Max Puckett and Jim Lytle provided hospitable support for our use of the Granite Canyon research station, run by the State of California Department of Fish and Game as their Marine Pollution Laboratory.

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Table 1. A comparison of pod size estimates made by two teams of paired observers independently tracking gray whales through the viewing area at Granite Canyon, January 1997. TQ = track quality, a rating system that subjectively described the perceived accuracy of the track record, where a TQ of 1 was an excellent record and a TQ of 5 was unreliable.

TQ	n	Pod size discrepancy = 0	Pod size discrepancy = 1	Pod size discrepancy >1
1	12	9 (75%)	2	1
2	7	5 (71%)	1	1
3	3	1 (33%)	2	0
4	5	3 (60%)	2	0
5	7	4 (57%)	3	0

Table 2. Comparisons of gray whale pod size estimates made by teams tracking the pods versus observers on the standard watch at Granite Canyon in January 1997. Cells indicate the number of estimates corresponding to the respective pairing (e.g., 36 times both methods agreed that there was only 1 whale in a pod). Numbers in bold are the samples in which both methods agreed on the pod size.

	Pod sizes recorded on the standard watch								
Trackers' pod sizes	1	2	3	4	5	6	7	8	9
1	**36**	5	0	0	0	0	0	0	0
2	20	**17**	0	0	0	0	0	0	0
3	2	8	**2**	1	3	0	0	0	0
4	2	3	2	**6**	3	0	0	0	0
5	3	5	3	3	**2**	0	0	0	0
6	2	2	3	1	0	**0**	4	0	0
7	0	1	0	0	0	0	**0**	0	0
8	0	0	0	0	0	0	1	**0**	1
9	0	0	0	0	0	0	0	0	**0**

Table 3. Estimates of group sizes of gray whales migrating past a shore-based counting station compared to group sizes established by teams tracking the whales through the viewing area near Granite Canyon in January 1997.

Pod size estimates	Means of "True size"	Variance	n	t	p (two-tail)	Bias
1	1.80	1.60	65	-5.10	<<0.001	-0.80
2	2.90	2.34	41	-3.78	<0.001	-0.90
3	4.46	2.60	13	-3.27	0.003	-1.46
>3 ($\bar{x} = 5.12$)	4.76	1.94	25	+0.91	0.366	0.00

Table 4. A comparison of corrections of estimated pod sizes of gray whales migrating past a shore-based counting station near Granite Canyon.

Pod size estimates	Reilly (1981)	n	Laake et al. (1994)	n	DeAngelis et al. (1997)	n	This study	n
1	+0.350	225	+0.941	102	+0.36	106	+0.80	65
2	0	101	+0.646	82	0	61	+0.90	41
3	0	28	+0.607	28	0	45	+1.46	13
>3	+0.333	27	+0.250	28	+0.35	30	0.00	25

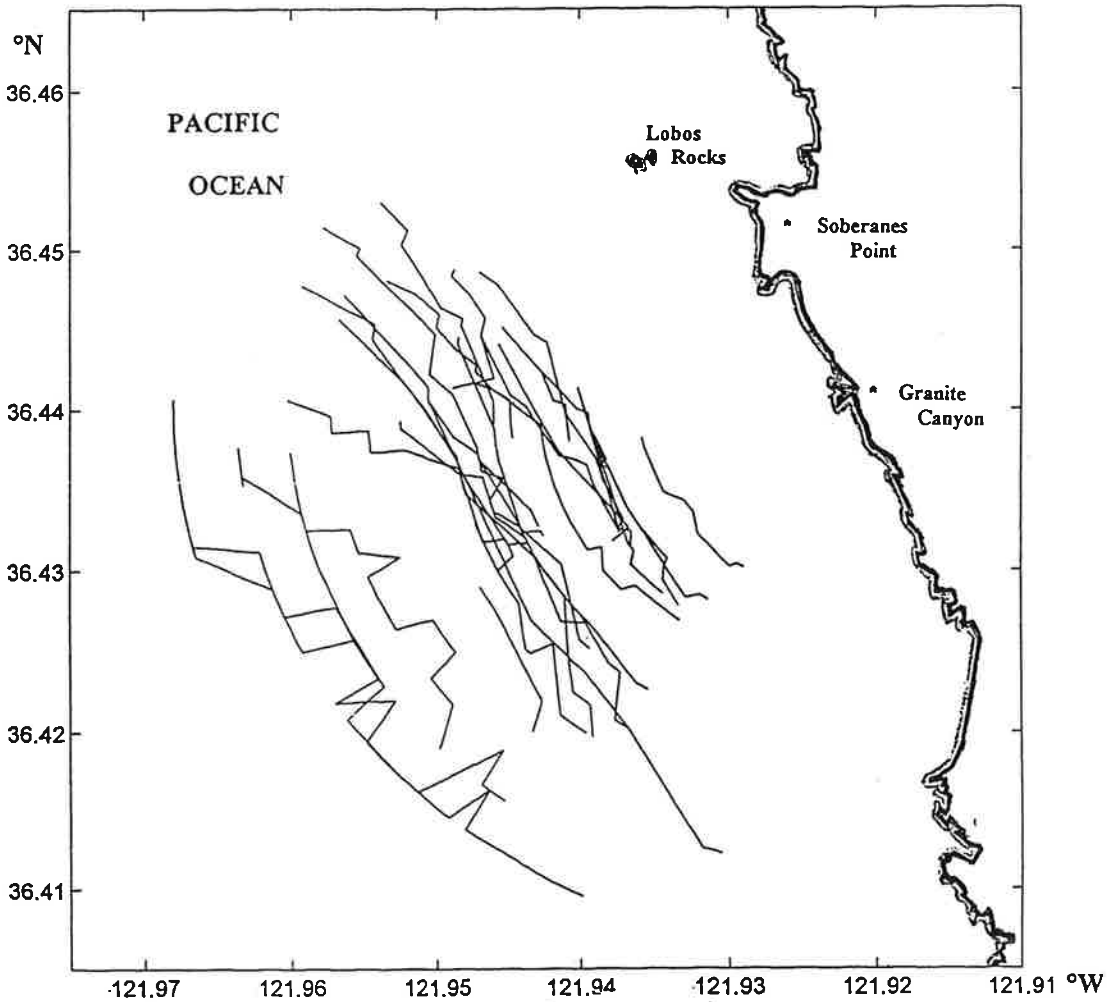

Figure 1. Tracklines of gray whales migrating south past a research station at Granite Canyon, California, in January 1997. Sighting locations were determined by teams of shore-based observers using reticled binoculars with magnetic compasses.

ABUNDANCE AND DISTRIBUTION OF MARINE MAMMALS IN WASHINGTON AND BRITISH COLUMBIA INSIDE WATERS, 1996

Jeffrey L. Laake[1], Robert L. DeLong[1], John Calambokidis[2], and Steve Osmek[2]

[1] National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington, 98115

[2] Cascadia Research
218½ W. Fourth Avenue
Olympia, Washington, 98501

Abstract

Aerial line-transect surveys were conducted during August 1996 primarily to estimate harbor (*Phocoena phocoena*) and Dall's porpoise (*Phocoenoides dalli*) abundance in five regions, encompassing U.S. and Canadian waters of the Strait of Juan de Fuca, San Juan/Gulf Islands, and Strait of Georgia. The surveys were conducted by Cascadia Research Collective under contract to the National Marine Mammal Laboratory. We provide a summary of the results that are fully described in Calambokidis et al. (1997).

Abundance Estimates

Harbor Porpoise

A total of 6,263 km (3,382 nmi) of on-transect effort (Fig. 1) was completed using a twin-engine high-wing aircraft flying at 90 knots and an altitude of 600 ft. Three observers searched for marine mammals through side bubble windows and a downward viewing port. Out of 1,505 groups sighted (3,340 animals) while on-effort, 1,074 were harbor seals, 311 were harbor porpoise, and 76 were Dall's porpoise. From these data, abundance of harbor porpoise and Dall's porpoise was estimated for U.S. and Canadian waters during 1996. In addition, the 1991 estimates were updated by restricting the survey data to U.S. waters. Table 1 summarizes the uncorrected and corrected abundance estimates for the Inland Washington stock occurring in U.S. waters during 1991 and 1996. The estimate of abundance uncorrected for g(0) increased between 1991 and 1996 but the difference is not significant (Z=0.8, P=0.42). The current stock assessment report (SAR) (Barlow et al. 1995) specifies a PBR of 27 harbor porpoise based on the 1991 estimate that had included survey areas in Canadian waters. The re-analysis of the 1991 survey data yields a PBR of 21 and for the 1996 estimate the PBR is 25.

Table 1. N_{MIN} values for the Inland Washington stock of harbor porpoise based on abundance estimate uncorrected for g(0) and corrected for g(0) using alternative estimates from Laake et al. (1997). $g_1(0)=0.292$ (SE=0.107) corrects for availability and perception bias, while $g_2(0)=0.338$ (SE=0.061) only corrects for availability bias and assumes all harbor porpoise near the surface are detected.

Year	Method	Abundance	CV	N_{MIN}
1991	Uncorrected for g(0)	856	0.17	744
	Corrected for $g_1(0)$	2933	0.40	2116
	Corrected for $g_2(0)$	2533	0.25	2064
1996	Uncorrected for g(0)	1025	0.15	903
	Corrected for $g_1(0)$	3509	0.40	2545
	Corrected for $g_2(0)$	3033	0.24	2494

Dall's Porpoise

The current incidental mortality of the California/Oregon/Washington stock of Dall's porpoise is well below 10% of the estimated PBR and it is not a strategic stock. However, as part of the harbor porpoise surveys in 1991 and 1996, sightings of Dall's porpoise were recorded and an analysis of abundance for the inland waters was included in Calambokidis et al. (1997). Table 2 summarizes the 1991 and 1996 estimates of Dall's porpoise in Washington's inland waters.

Table 2. N_{MIN} values for Dall's porpoise in inside waters of Washington based on abundance estimate uncorrected for g(0) and corrected for g(0) using alternative estimates from Laake et al. (1997) for harbor porpoise. $g_1(0)=0.292$ (SE=0.107) corrects for availability and perception bias, while $g_2(0)=0.338$ (SE=0.061) only corrects for availability bias and assumes all porpoise near the surface are detected.

Year	Method	Abundance	CV	N_{MIN}
1991	Uncorrected for g(0)	802	0.31	621
	Corrected for $g_1(0)$	2747	0.48	1872
	Corrected for $g_2(0)$	2373	0.36	1769
1996	Uncorrected for g(0)	263	0.16	230
	Corrected for $g_1(0)$	900	0.40	651
	Corrected for $g_2(0)$	778	0.24	638

Distribution

Nine different marine mammal species were observed during the surveys. Sufficient sample sizes were available for the three most commonly sighted species, harbor seals (n=862, Fig. 2), harbor porpoise (n=261, Fig. 3), and Dall's porpoise (n=68, Fig. 4) to determine their habitat preferences related to water depth, distance to shore and sighting rate differences for 352 one square kilometer geographic cells. These species were found at most water depths, but sighting rates of harbor seals were significantly greater at shallower depths (two-way ANOVA, $P=0.010$) and Dall's porpoise sighting rates were significantly higher in the deeper waters ($P=0.001$). Harbor porpoise distribution varied significantly by depth ($P=0.013$), with more animals occurring in deeper waters of the San Juan/Gulf Island regions. In the Strait of Juan de Fuca, no clear pattern in the depth distribution could be ascertained. The significant regional differences for harbor seal and harbor porpoise were explained by the low sighting rates in the Strait of Georgia, where only these two species were seen. Distance to shore was only a significant predictor for harbor seal distribution ($P<0.000$). Because harbor seals and harbor porpoise, the most common species incidentally taken in these waters, ranged widely and were found at all depth and distances to shore, closing specific areas to gillnet fisheries may not be an effective method to reduce take levels.

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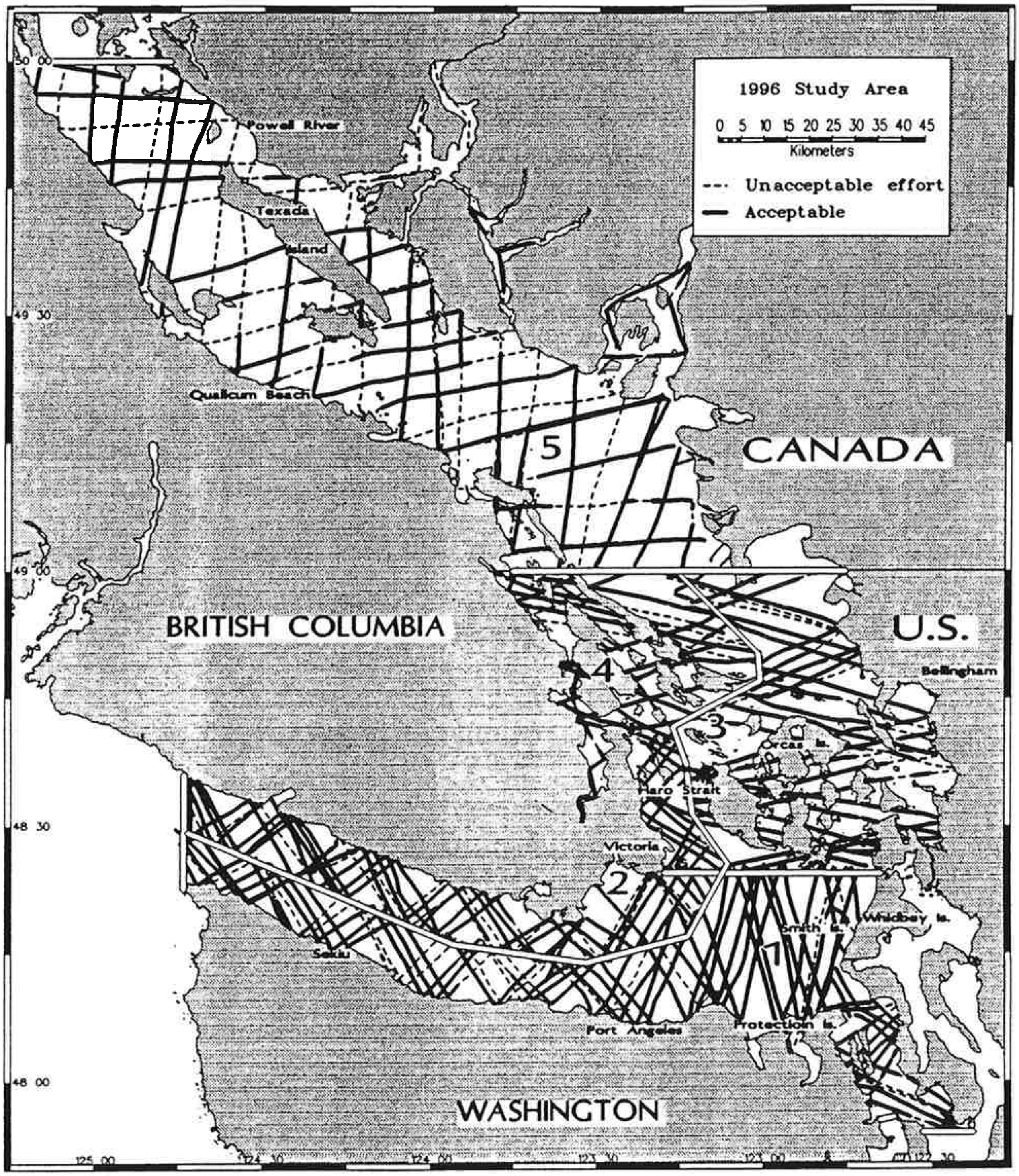

Figure 1. Transect lines and region boundaries for aerial surveys flown in 1996. Survey effort in good weather conditions (Beaufort sea state of 2 or less and cloud cover of 25% of less) is shown by a solid line and survey effort in poor conditions by dashed lines.

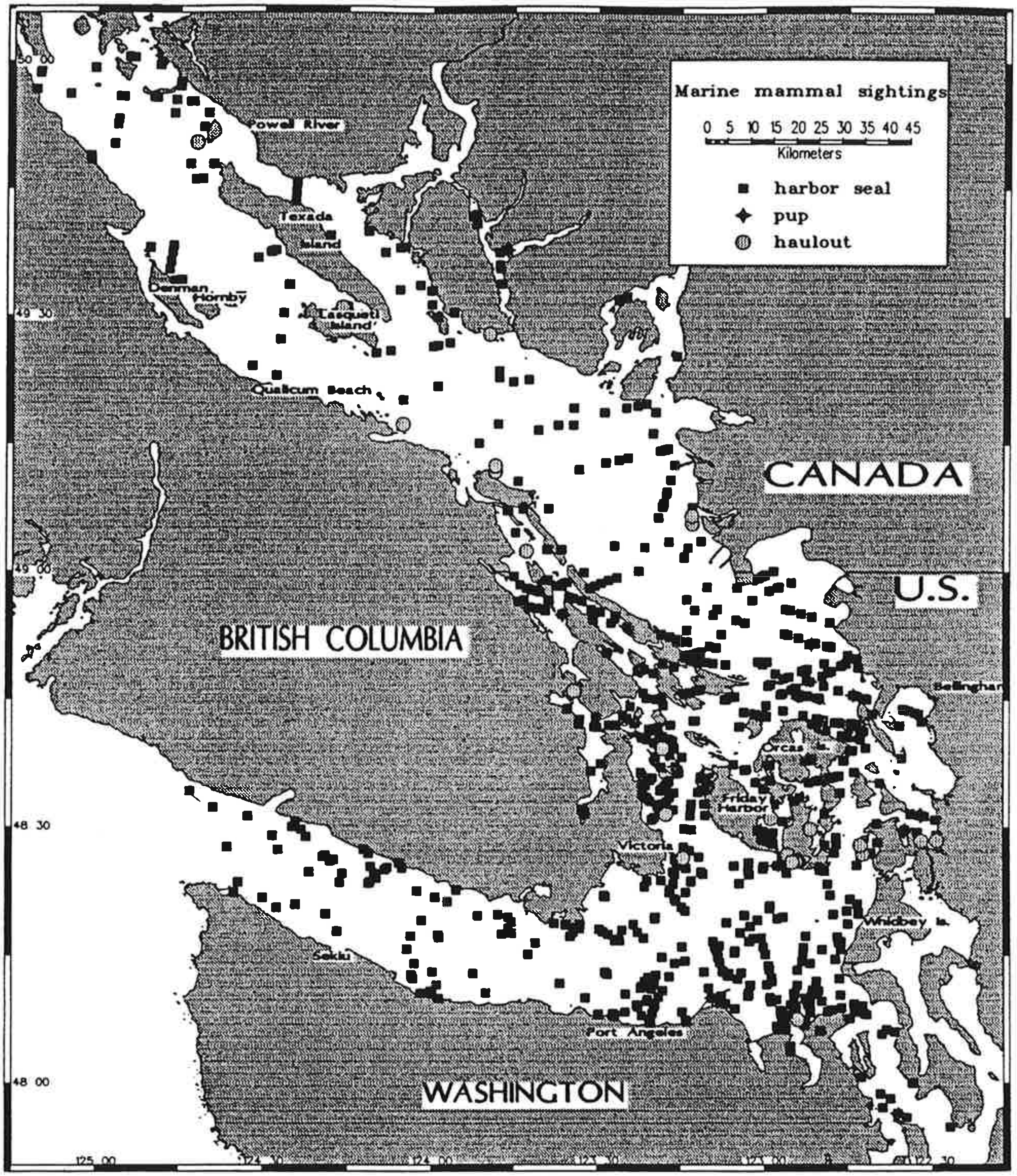

Figure 2. On-effort sightings of harbor seals, pups, and haul out sites made under acceptable visibility conditions.

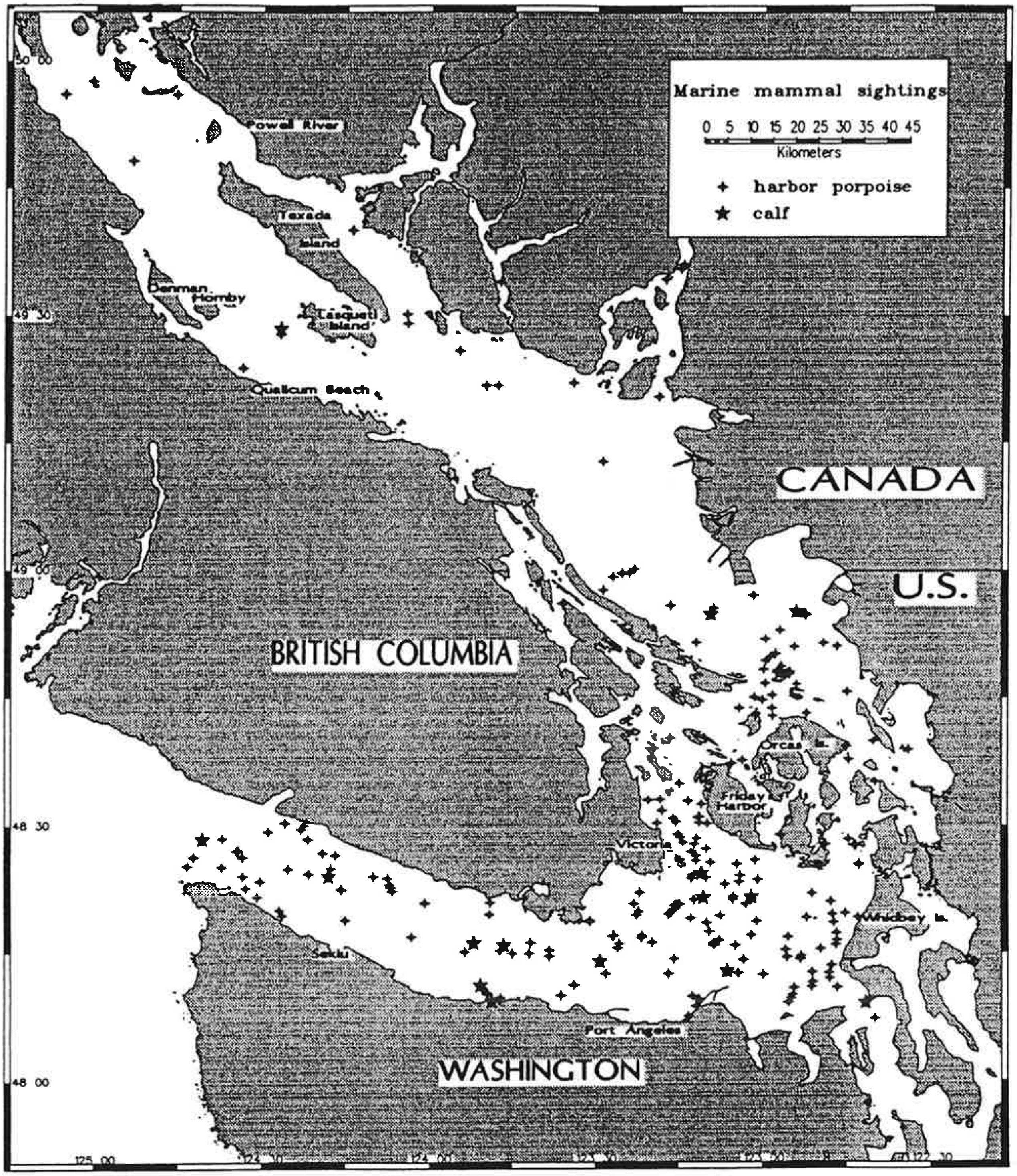

Figure 3. On-effort sightings of harbor porpoise and calves seen under acceptable visibility conditions.

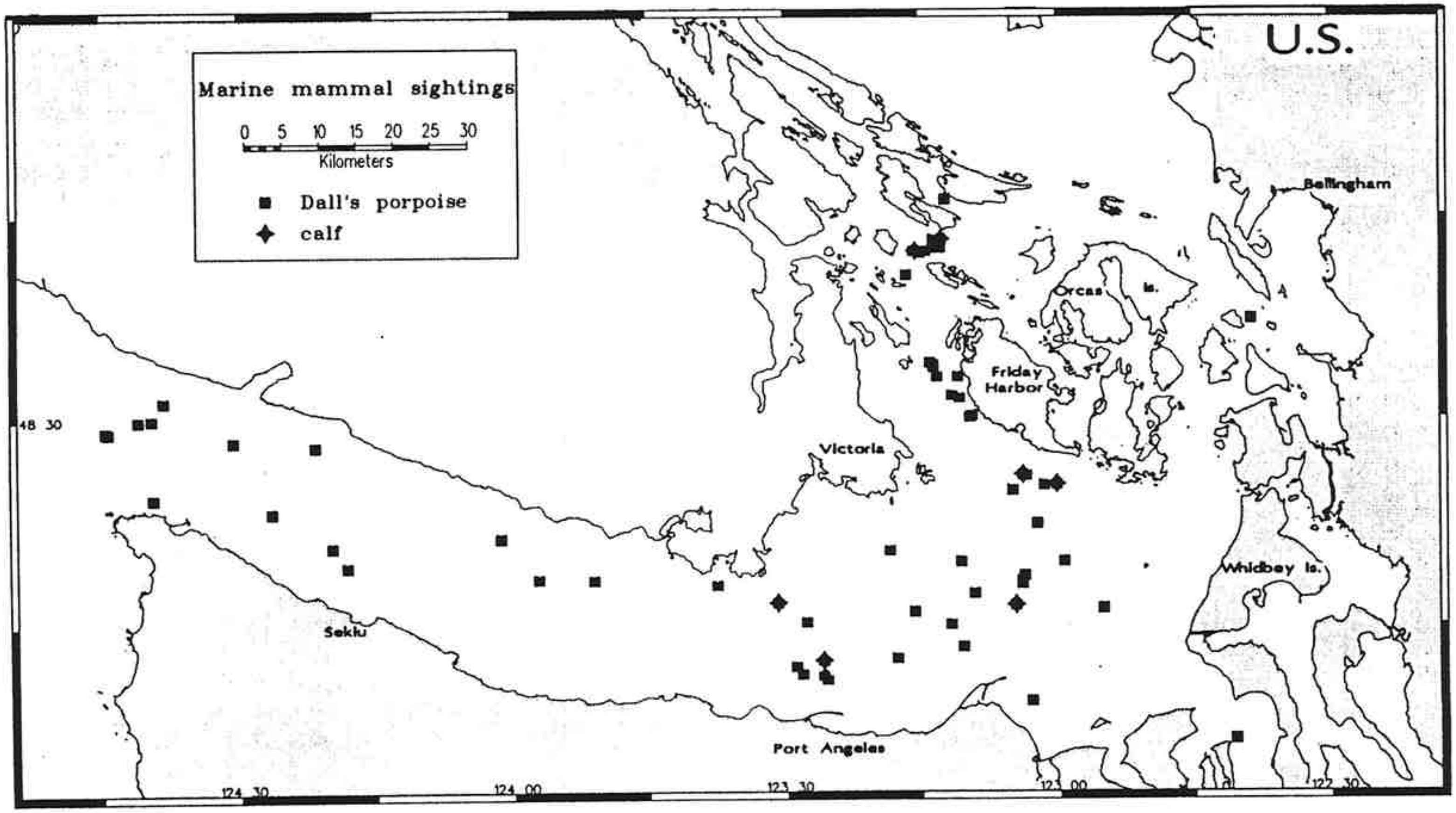

Figure 4. On-effort sightings of Dall's porpoise and calves seen under acceptable visibility conditions.

EVALUATION OF EFFECTIVENESS OF PINGERS TO REDUCE INCIDENTAL ENTANGLEMENT OF HARBOR PORPOISE IN A SET GILLNET FISHERY

Jeffrey L. Laake, Patrick J. Gearin, Merrill E. Gosho, and Robert L. DeLong

National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington, 98115

Abstract

Field tests were conducted with four set gillnets to evaluate the effectiveness of acoustic alarms (pingers) to reduce the incidental entanglement of harbor porpoise (*Phocoena phocoena*) in the Spike Rock tribal fishery in northern Washington during the summers of 1995 and 1996. Each net was alternately fished with and without pingers. In both the 1995 and 1996 experiments the nets had significantly lower entanglement rates when pingers were attached. In 1996 from a shore-based site, we observed harbor porpoise locations relative to one of the set gillnets. When the net was alarmed, harbor porpoise were effectively displaced within a radius of 125 m around the net. We provide summaries of these studies which are described in detail in other publications.

Pinger Mortality Studies

Four 100 fathom (183 m) set gillnets were alternately fished without and with pingers in the Spike Rock Fishery Area, seaward of Shi Shi Beach, which is within the Olympic Coast National Marine Sanctuary at the northwestern edge of the Olympic National Park in Washington State (Fig. 1). Eleven pingers were placed on the nets at 16.6m intervals. The pingers produced a broadband signal with peaks at 3 and 20 kHz, with overall source levels between 121.7 and 124.7 dB re 1 micropascal at 1 m. During 1995, 52 days were fished without pingers and 19 harbor porpoise were entangled and 51 days were fished with pingers and only 1 harbor porpoise was entangled. The 1995 data were analyzed by Gearin et al. (1996) and reported to the International Whaling Commission (IWC). The 1995 experiment demonstrated a significant reduction in incidental mortality; however, the pinger treatment was not balanced through time because of pinger failure. Therefore, the experiment was repeated in 1996 to achieve better temporal balance and to allow for observational studies of porpoise around the net during alarmed and unalarmed states. The 1996 results (Table 1) also demonstrated that pingers significantly reduced incidental harbor porpoise mortality ($\chi^2 = 11.2$, 1 df, P<0.001).

Table 1. Number of net days classified by alarm status (with or without pingers) and whether one or more harbor porpoise were entangled in the net (total number of porpoise entangled in parentheses).

Year		Entanglement Yes	Entanglement No	Total
1995	Alarmed	1(1)	50	51
	Not alarmed	9 (19)	43	52
	Total	10 (20)	93	103
1996	Alarmed	1(1)	60	61
	Not alarmed	14 (28)	46	60
	Total	15 (29)	106	121

Harbor Porpoise Observations

Large and small-scale fishery experiments have demonstrated that attaching acoustic devices (pingers) on gill nets reduces harbor porpoise entanglement and mortality (Kraus et al. 1995, Gearin et al. 1996). However, the mechanism for mortality reduction has not been investigated and is unknown. We conducted shore-based observations of a set gill net that was alternately alarmed and unalarmed for 2- to 5-day periods during 27 days between 11 July - 6 August 1996. The results of the observation study are described in detail by Laake et al. (in prep.).

Observations of the Spike Rock Fishery Area were made from a site on an exposed bluff northeast of Shi Shi Beach (48°16.5'N, 124°40.7'W). An observation team, unaware of the alarm status of the nets, conducted 30- to 45-minute systematic watches of the field of view. One observer scanned the inshore area while another scanned the offshore area, and a third person recorded data. The four-person team, including a rest position, rotated every 45 min. When only 3 observers were available, rotations were made every 30 min. Searching was conducted through 7x50 binoculars (Fujinons), which have a 5.44° optical field of view with 14 vertical reticle marks (17' per reticle mark) and 16 horizontal reticle marks (not used). An internal magnetic compass provided 360° bearings, accurate to within 3°. The search consisted of a systematic, continuous scan horizontally across the survey area, swinging the binocular from right to left or left to right, but not back and forth, at 7-8 min per scan.

Our primary interest was whether harbor porpoise were displaced from the region surrounding the net when pingers were attached. For each surfacing, we computed the closest distance between the surfacing and net #10, which was closest to the observation site. We constructed distributions for the distance from each surfacing to net #10, when it was alarmed and unalarmed. Because multiple observations of surfacing harbor porpoise through time will obviously be very dependent, standard statistical distribution tests (e.g., Kolmogorov-Smirnov) that assume independence would not be valid. Instead, based on a graphical examination of the distributions, we chose a distance of 125 m as the radius of a displacement region and defined the random variable y_i =1 if harbor porpoise were seen surfacing once or more within the displacement region during day I and y_i =0 if they were not seen in the displacement region. If the proportion of days in which y_i =1 (p=$Pr(y_i$ =1)) were significantly different between alarmed (p_a) and unalarmed (p_u) periods, we would conclude that the alarms displaced the porpoise. The statistical methods used to test the hypothesis are described in Laake et al. (in prep.).

Harbor porpoise groups were sighted on 501 occasions in 135.7 hrs of observation during 27 days. The amount of observation time varied between 0.3 and 9 hrs/day in excellent to fair visibility conditions. Nets were attended typically during mid- to late-afternoon. When the alarm status of net #10 changed mid-day, we excluded the afternoon portion of the observation from the analysis so we did not have to model dependence within a day as well as between days. This excluded 14.3 hrs, resulting in 50.4 hrs of observation during 13 days when net #10 was unalarmed and 71 hrs during 14 days when net #10 was alarmed.

Harbor porpoise sightings were primarily clustered to the north of net #10 (Fig. 2), but when net #10 was unalarmed, harbor porpoise were seen closer to the net. The distribution of distances between sightings and net #10 (Fig. 3) suggested porpoise were displaced 100 to 150 m from the net. We chose 125 m as the radius of the displacement region for testing the significance of an alarm effect. Harbor porpoise were seen within the displacement region on 5 of the 13 days when the net was not alarmed, but on only 1 of the 14 days when the net was alarmed (Table 2). Without considering the influence of hours watched and visibility, this is not a significant result (P=0.08, Fisher's exact test). However, during 7 unalarmed and 5 alarmed days when fewer than 4 observation hours were conducted (Table 2), harbor porpoise were never seen within the displacement region. Whereas, during days in which 4 or more hours were observed,

Table 2. Proportion of observation days in which harbor porpoise were seen within 125 m of net #10, classified by alarm state of net #10, number of observation hours, and visibility conditions.

		Average Visibility		
	Hours Watched	Ex-Good (<3)	Good - Fair (≥3)	Total
Alarm Off	< 4	0/1	0/6	0/7
	≥ 4	2/2	3/4	5/6
	Total	2/3	3/10	5/13
Alarm On	< 4	0/1	0/4	0/5
	≥ 4	0/4	1/5	1/9
	Total	0/5	1/9	1/14

harbor porpoise were seen in all but 1 unalarmed day, but on only 1 of 9 alarmed days. Fisher's exact test yields a significant result (P=0.01) when the analysis is restricted to days with 4 or more observation hours. Visibility does not appear to be very important, except that there were fewer hours of observation on days when observations were halted because of poor visibility conditions. Even though we demonstrated that harbor porpoise were less likely to surface within a radius of at least 125 m around the net, we are uncertain whether the porpoise were repelled by the alarms or whether it was their prey that were repelled.

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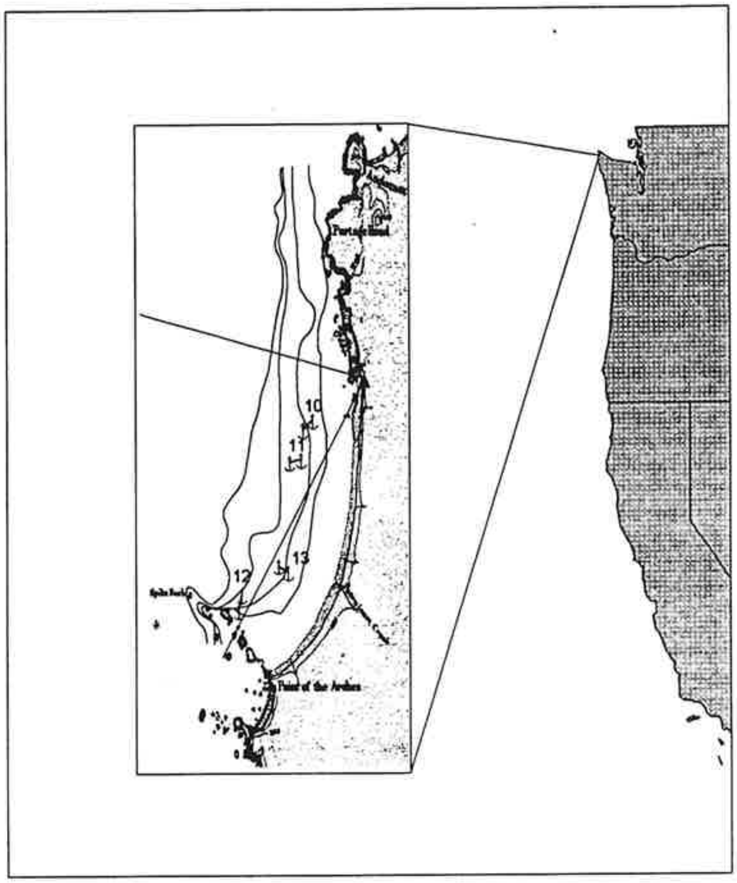

Figure 1. Spike Rock Fishery area. Approximate field of view (56°) indicated by lines emanating from base camp position. Nets, numbered 10-13, indicated by anchors. Approximate bathymetric contours are indicated for 4,6,8 and 10 fathoms.

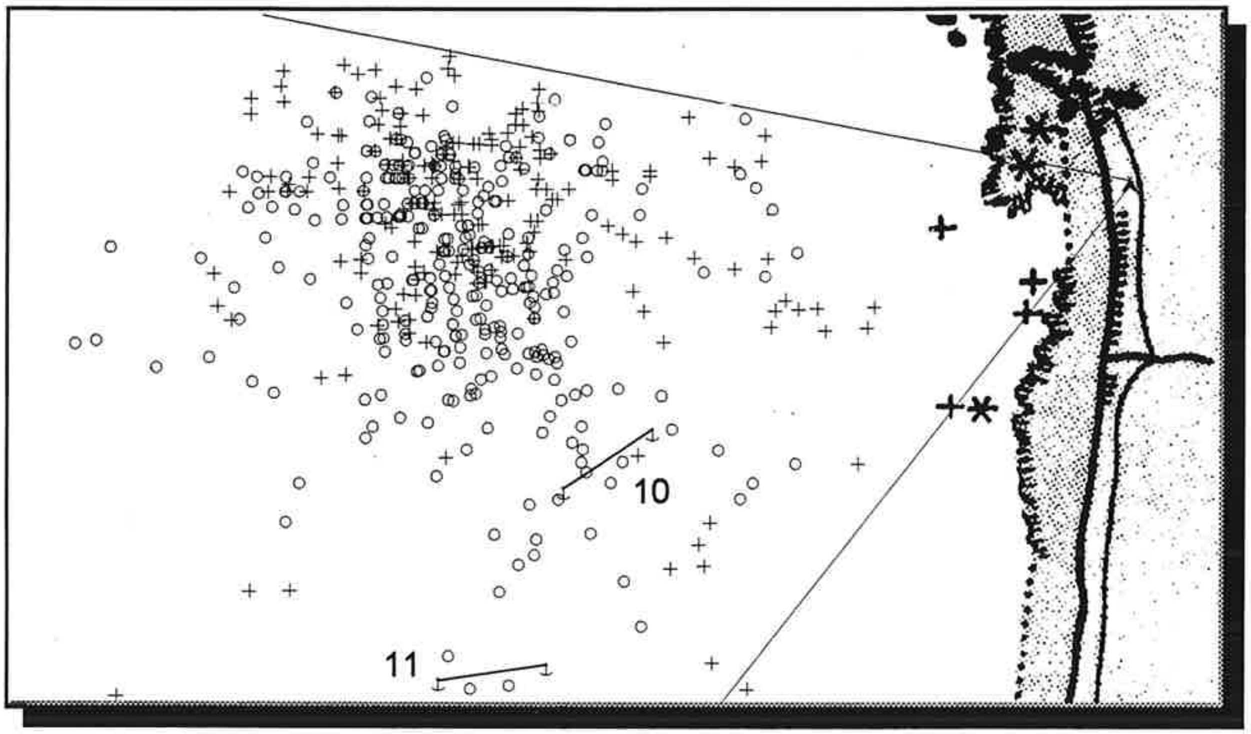

Figure 2. Positions of harbor porpoise sightings when net #10 was unalarmed (circle) and alarmed (+).

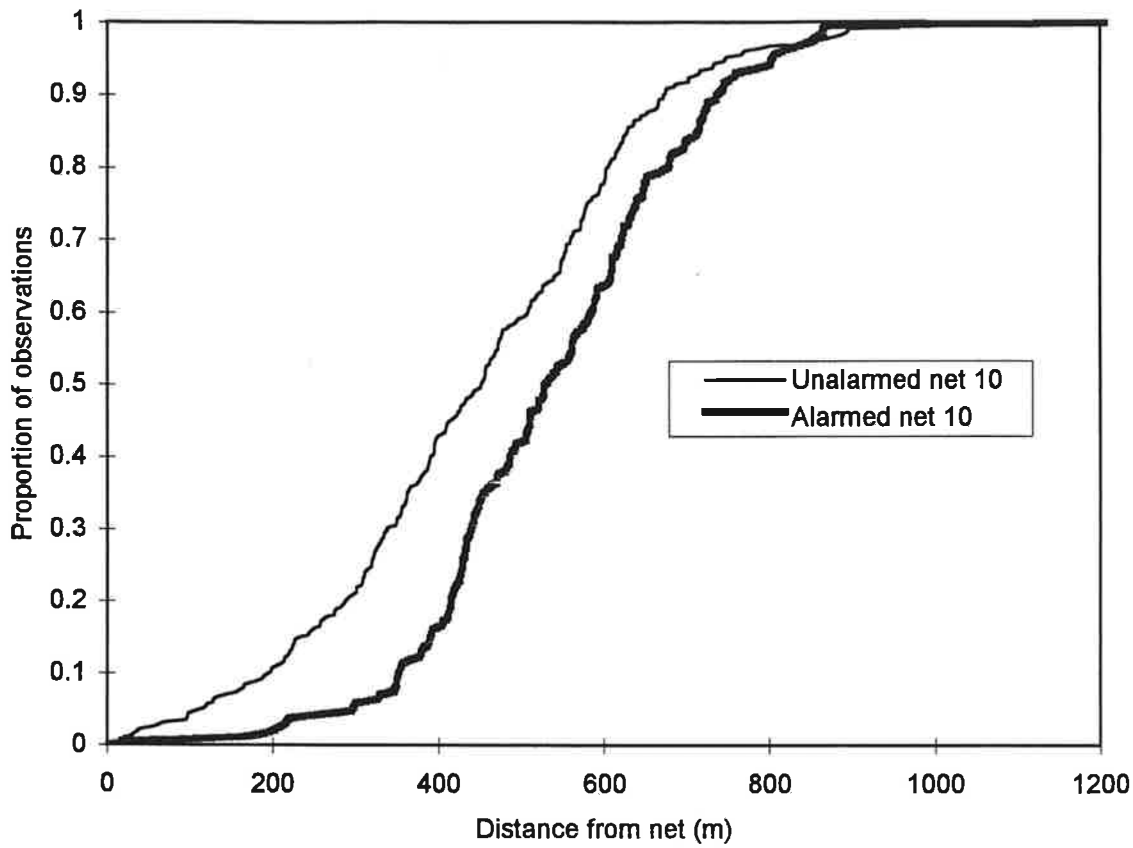

Figure 3. Cumulative distributions of distances between harbor porpoise sightings and net #10 when the net was alarmed and unalarmed.

ASSESSMENT OF HARBOR SEALS IN WASHINGTON AND OREGON, 1996

Steven J. Jeffries[1], Robin F. Brown[2], Harriet R. Huber[3], and Robert L. DeLong[3]

[1] Washington Department of Fish and Wildlife
Marine Mammal Investigations
7801 Phillips Road SW
Tacoma, Washington 98498

[2] Oregon Department of Fish and Wildlife
7118 N.E. Vanderberg Ave.
Corvallis, Oregon 97330

[3] National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington 98115

Abstract

In 1996, the number of harbor seals (*Phoca vitulina*) counted in Washington on aerial surveys during the pupping season was 21,820. In Oregon, from aerial survey data collected by the Oregon Department of Fish and Wildlife, the number of seals counted in 1996 was 6,421. When these data were separated into two stocks, there were 17,106 seals in the Washington and Oregon coastal stock and 11,135 seals in the Washington inland waters stock. Using the 1.53 correction factor to account for seals in the water during surveys, the corrected estimate for the coastal stock was 26,172 seals (95% C.I. = 22,946 to 29,853) and the corrected estimate for the inland waters stock was 17,036 seals (95% C.I. = 14,853 to 19,540). The annual rate of increase between 1983 and 1996 was similar for the two stocks: 4% for the coastal stock and 6% for the inland stock. The annual rate of change between 1991 and 1996 was quite different for the two stocks: the coastal stock decreased 1.6% annually, which was not significantly different from zero ($p = 0.083$) and the inland stock increased 10% annually, which was significantly different from zero ($p = 0.034$).

Introduction

Harbor seals (*Phoca vitulina*) are the most abundant pinniped in Washington: their distribution includes the outer Olympic Peninsula coast, the coastal estuaries (Grays Harbor and Willapa Bay), the Strait of Juan de Fuca, the waters around the San Juan Islands, Eastern Bays, Puget Sound, and Hood Canal (Fig. 1). Harbor seals are also the most common pinniped in the Columbia River and coastal Oregon. They pup and breed in all of these regions. In the past, harbor seals in Washington and Oregon were killed by state-financed bounty hunters as a method of population control because the seals were considered fish predators in conflict with commercial and sport fisheries. Since the termination of the harbor seal bounty program and the passage of the Marine Mammal Protection Act in 1972, harbor seal numbers in Washington and Oregon have increased (Jeffries 1985, Brown 1997).

The timing of harbor seal pupping follows a cline along the west coast of North America, with pups born earlier south to north from Mexico to Canada (Bigg 1973, Bigg and Fisher 1975). In Washington, the timing of pupping is complicated by variability within the state: a slightly earlier (2 weeks) pupping in the coastal estuaries than along the coast, a considerably later (2 months) pupping in the inland waters (San Juan Islands, Strait of Juan de Fuca, Eastern Bays, and Puget Sound), and an extended pupping season from August until January in Hood Canal. Based on geography and timing of pupping, Washington State was divided into six regions for aerial survey assessment: 1) coastal estuaries, 2) outer Olympic Peninsula coast, 3) Strait of Juan de Fuca and San Juan Islands, 4) Eastern Bays, 5) southern Puget Sound, and 6) Hood Canal (Fig. 1). There are 319 known harbor seal haulout sites in Washington. Because of the differences in pupping phenology, the time constraints of the low tide window, the large number of harbor seal haulout sites, and distances between haul out sites in Washington, aerial surveys were partitioned by pupping phenology and by region (Table 1). Harbor seals on the Oregon coast and in the Columbia River were surveyed by the Oregon Department of Fish and Wildlife (ODFW) between late May and early June (Brown 1997).

Methods

Aerial surveys were flown at low tide in all regions except Hood Canal where maximum numbers of seals haul out at high tide (Calambokidis et al. 1979). Two to four surveys were flown in each region during the pupping season. Low regional counts due to incomplete surveys, disturbance, weather, or unknown causes were discarded. Low regional counts were defined as counts that were >25% lower than other regional counts in 1996.

Surveys of all known haulout sites were flown during the identified period of peak pupping at the coastal estuaries (Stein 1989), outer Olympic Peninsula coast (Moss 1992), Strait of Juan de Fuca (Everitt 1980, Gearin 1979), and Hood Canal (Calambokidis et al. 1984). Multiple flights were scheduled for each "tidal window" to compensate for bad weather. Some flights were canceled or incomplete because of bad weather. At each haulout site, photographs were taken as well as a visual estimate of the total number of animals hauled out, including pups.

Surveys were flown in a single engine, high-winged airplane (Cessna 172, 182, or 185) at 800 ft altitude at 80 knots from 2 hrs before low tide to 2 hrs after low tide. Photographs were taken with an SLR 35 mm hand-held camera equipped with a 70-210 mm zoom lens and polarizing filter using Kodak High Speed Ektachrome film (ASA 200 or 400). The primary observer (right front seat) estimated the total number of animals and photographed sites, the secondary observer (right rear seat) recorded sites, estimates and comments. Small groups ($\pm$ 25 seals), which were possible to count accurately from the plane, were not necessarily photographed.

Photos from the aerial surveys were projected onto a whiteboard in the laboratory and a mark was made for each animal to prevent under- or overcounting. Photo counts were repeated at least twice to ensure accuracy. Similar methods were used in Oregon surveys and are described in Brown (1997).

Data Analysis

Multiple surveys were attempted in all regions. Mean ($\bar{x}$), Standard Error of the mean (SE ($\bar{x}$)), Coefficient of Variation (C.V. = SE($\bar{x}$)/$\bar{x}$), and 95% Confidence Intervals (C.I.) were determined for counts.

The state-wide mean total of harbor seals in Washington was calculated by summing the means from all survey regions. The state-wide SE ($\bar{x}$) for each year was calculated by summing the squares of the SE ($\bar{x}$) for each survey region and taking the square root of the sum. The 95% C.I.s were computed using the log normal distribution. Brown (1997) did not conduct multiple counts for seals in Oregon. Rather than assume no variability in the Oregon counts, we chose to use the maximum CV based on a single count (SD(x)/$\bar{x}$) from the coastal Washington counts as the CV for the Oregon count.

The annual rates of increase for the Washington and Oregon coastal stock and the Washington inland stock were determined by regressing the natural logarithm of the number of seals counted against time. The slope of the regression line provides the instantaneous rate of increase (r), which is converted to the annual rate of increase (R) by the relation e^r where e is the base of the natural logarithm.

Results

Between June and September 1996, complete surveys were flown on 17 days for a total of 87 hrs of flight time in Washington (Table 1). Counts from all regions in Washington totaled 21,820 harbor seals (Table 2). When these counts were divided between the two stocks in Washington, there were 10,685 seals counted in the coastal stock and 11,135 seals in the inland waters stock. Adding 1996 ODFW survey data on harbor seals in Oregon from Brown (1997) resulted in a count of 17,106 harbor seals in the combined Washington/Oregon coastal stock.

Between 1983 and 1996, the annual rate of increase for the Washington and Oregon coastal stock was 4% (Fig. 2); for the Washington inland stock during the same time period, the annual rate of increase was 6% (Fig. 3). In looking at the rates of increase of the two stocks in more recent years (1991-96), there were profound differences. There was an annual decrease of 1.6% ($t = 3.25$; $p = 0.083$) in the Washington and Oregon coastal stock (Fig. 4) and an annual increase of 10% ($t = 5.28$; $p = 0.034$) in the Washington inland waters stock (Fig. 5).

Using the correction factor of 1.53 to account for seals in the water during surveys (Huber 1995), the total estimate for seals in the inland waters was 17,036 seals. The 95% C.I. around the total estimate for the inland waters stock was 14,853 to 19,540 seals. For the Washington and Oregon coastal stock, the corrected estimate was 26,172 seals with a 95% C. I. of 22,946 to 29,853 seals.

Discussion

From 1983 to 1992 (the last survey covered by MMPA funding prior to the 1996 survey), the annual rate of increase was 7 % for the coastal stock and 8% for the inland stock. With the most recent set of surveys, the rate of increase since 1983 declined to 4% for the coastal stock and 6% for the inland stock. For the coastal stock, peak counts occurred in 1992 when 18,667 seals were counted compared to 17,106 seals counted in 1996. Since 1991, the coastal stock has declined 1.6% annually which is consistent with a population in equilibrium. For the inland stock, peak counts occurred in 1996 when 11,135 seals were counted. Since 1991, the inland stock has increased 10% annually.

The reason for the difference between the two stocks is unknown. A separate analysis of the Oregon data (from 1988 to 1996 the average annual rate of increase was 0.3%) indicates that state-wide counts may be approaching equilibrium (Brown 1997). The higher increase in the inland waters stock may be a result of seals from the boundary waters of the Strait of Georgia moving into the San Juan Islands area. It is also possible that the difference may be related to changes in haulout behavior of the two stocks of seals. Speculation on what could have caused changes in the haulout behavior include increased number of seals in the water during surveys because of increased disturbance or because of reduced food availability necessitating longer foraging periods or some other unknown reason.

Acknowledgments

Funding for this project was provided by the Marine Mammal Assessment Program, NMFS, NOAA, WDFW, and ODFW. Assistance in aerial surveys and slide counting was provided by Kirt Hughes, Dyanna Lambourn, Laura Matchulat, Sarah Meyers, and Susan Riemer. Aerial surveys were flown under the aegis of NMFS scientific research permit No. 835 granted to ODFW, WDFW, and NMML.

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Table 1. Regional aerial surveys of harbor seals in Washington, 1996.

REGION	DATES
Coastal Estuaries	June 4, 5, 6
Outer Olympic Peninsula Coast	June 18, 19, 20
San Juan Islands and Strait of Juan de Fuca	July 31, August 1, 2, 13, 14
Eastern Bays	August 13, 14, 15
Puget Sound	August 14, September 9, 10
Hood Canal	September 5, 17, 18

Table 2. Peak count, $\bar{x}$, SE ($\bar{x}$), and CV of harbor seal counts in each census region in Washington, 1996.

CENSUS REGION	Peak Count	Date of Peak	n	$\bar{x}$	SE ($\bar{x}$)	CV
Coastal Estuaries:						
Willapa Bay	3,333	6 June	3	3,191	58.7	0.02
Grays Harbor*	4,339	6 June	3	4,033	97.5	0.02
Olympic Peninsula Coast	3,465	19 June	2	3,461	5	0.00
Strait and SJI:						
Strait of Juan de Fuca	2,147	1 Aug	4	1,991	31.5	0.02
San Juan Islands	5,478	2, 14 Aug	2	5,460	151	0.03
Eastern Bays	1,557	14 Aug	3	1,473	59.4	0.04
South Puget Sound	1,152	10 Sept	3	1,109	12.6	0.01
Hood Canal	1,218	18 Sept	3	1,102	54.7	0.05
Washington total	22,689			21,820	208.4	0.01
Oregon total	-	-	1	6,421	268.8	0.04

* Utilized largest CV of Washington coastal sites to construct CV for Oregon count.

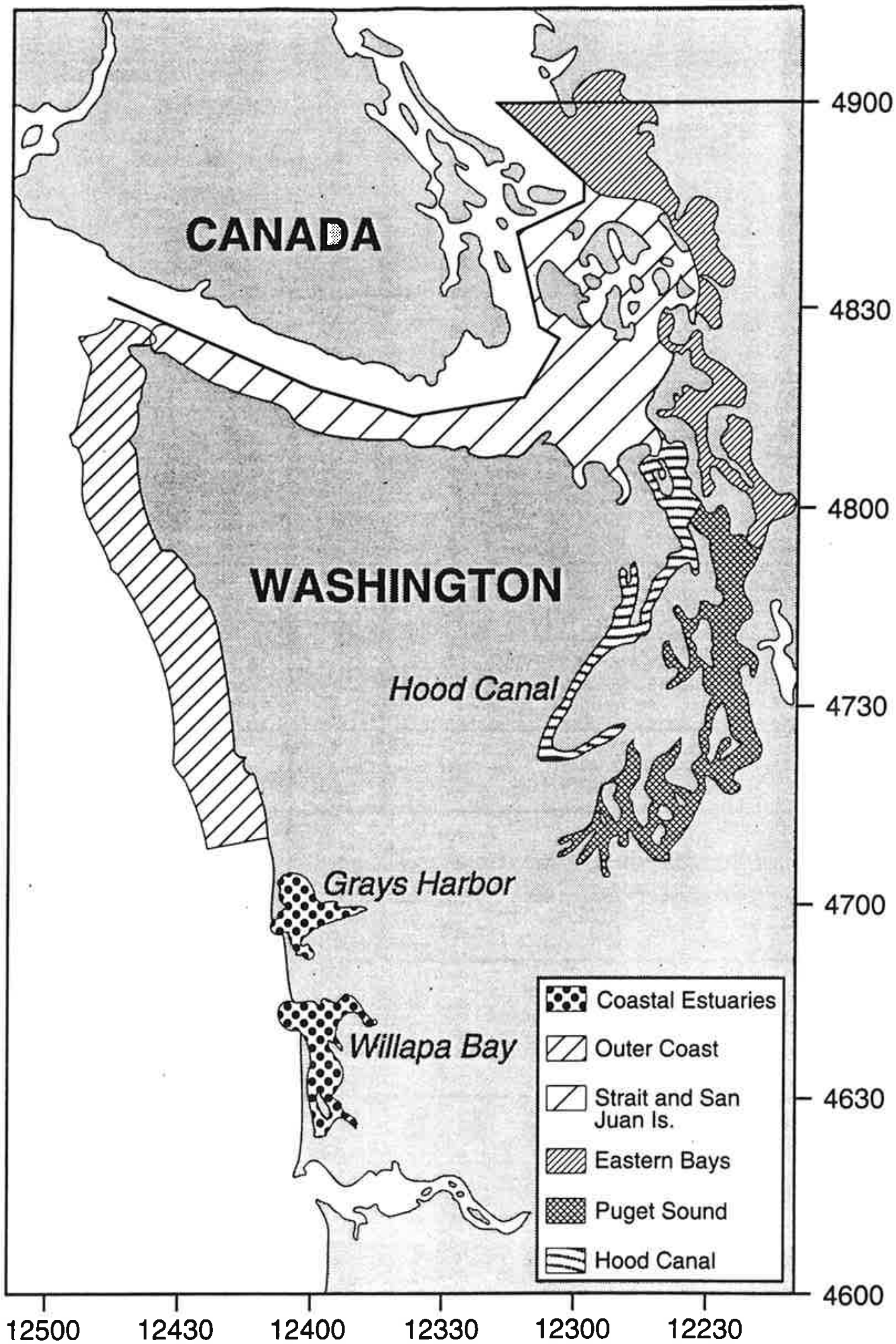

Figure 1. Regional survey sites for harbor seals in Washington.

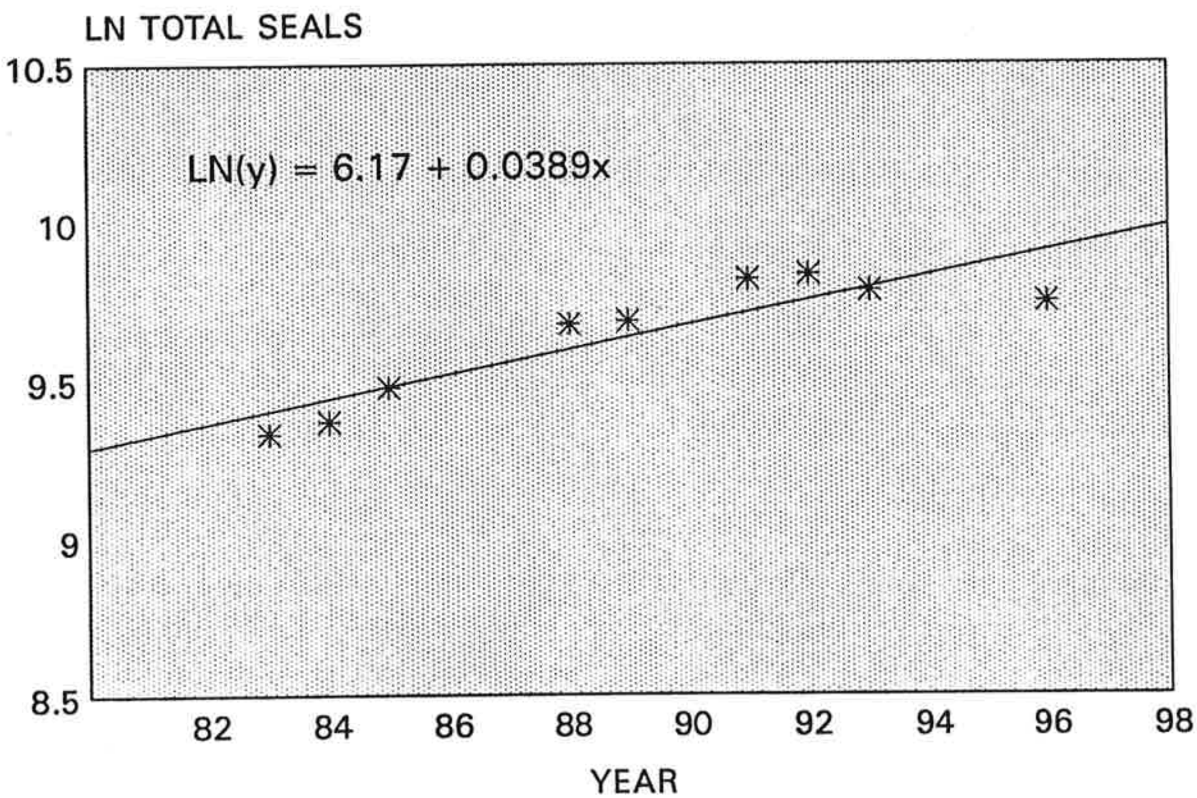

Figure 2. Regression of the natural log of total number of harbor seals in the Washington and Oregon coastal stock, 1983-96.

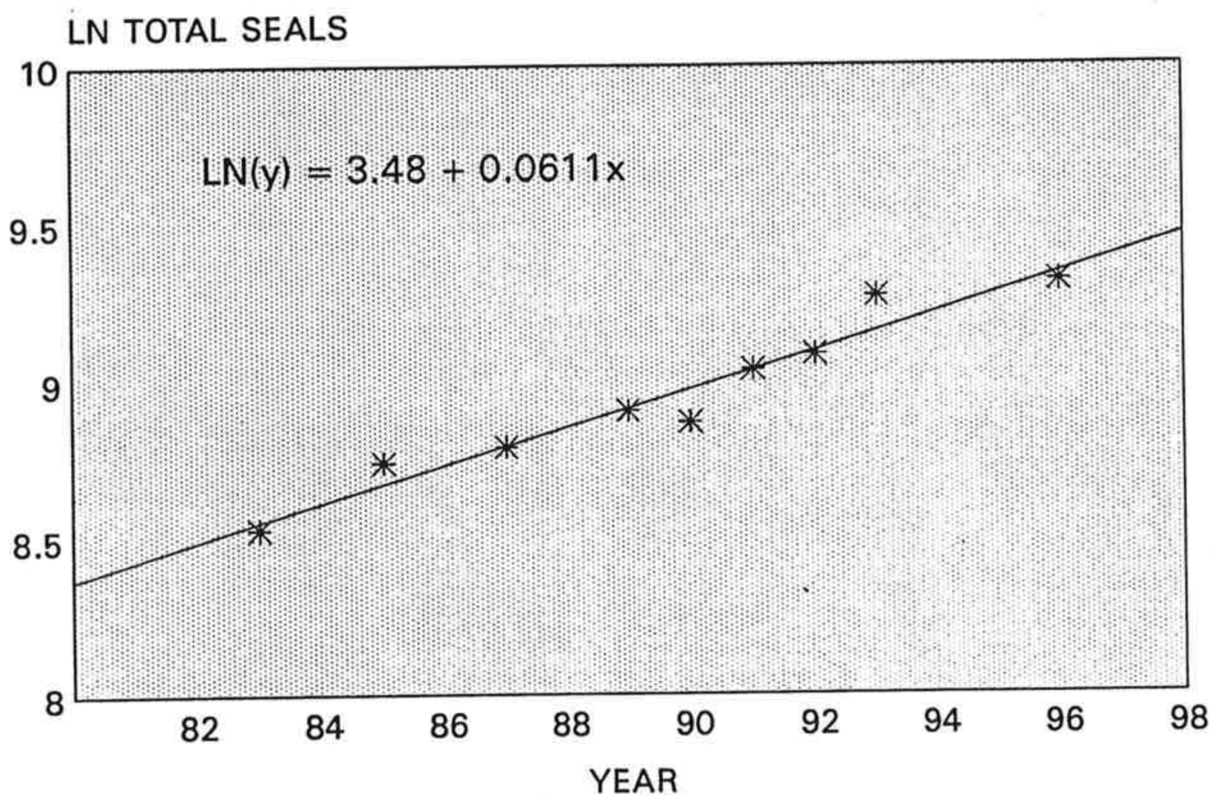

Figure 3. Regression of the natural log of total number of harbor seals in the Washington inland waters stock, 1983-96.

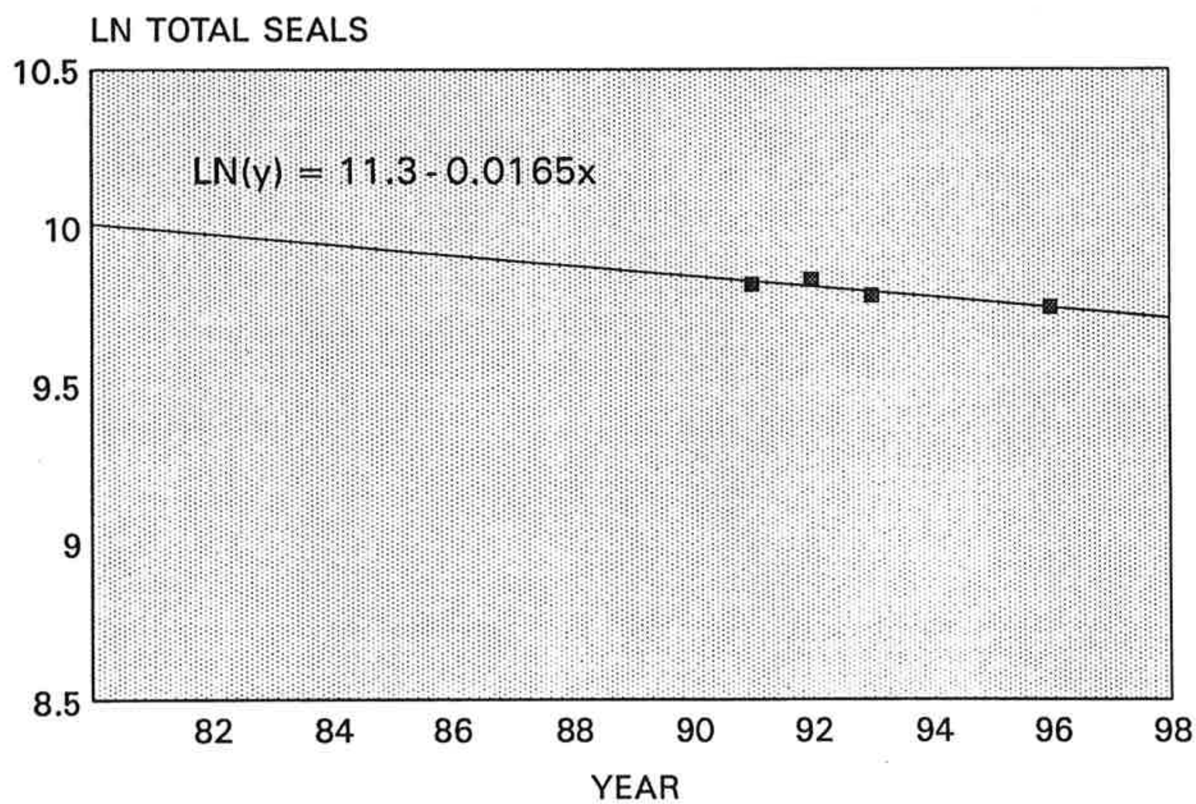

Figure 4. Regression of the natural log of total number of harbor seals in the Washington and Oregon coastal stock, 1991-96.

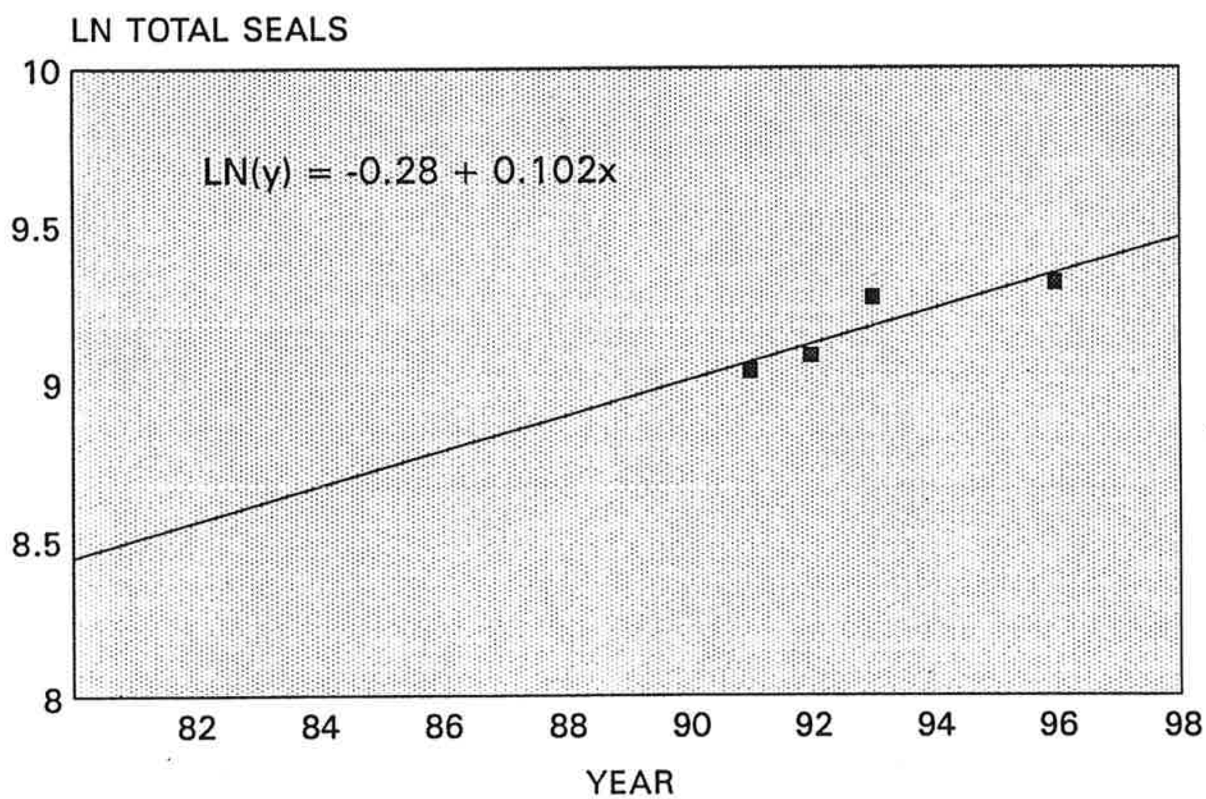

Figure 5. Regression of the natural log of total number of harbor seals in the Washington inland waters stock, 1991-96.

HARBOR SEAL LIFE HISTORY PARAMETERS IN WASHINGTON, 1996

Harriet R. Huber[1], Steven J. Jeffries[2], Dyanna Lambourn[2], and Robert L. DeLong[1]

[1] National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington 98115

[2] Washington Department of Fish and Wildlife
Marine Mammal Investigations
7801 Phillips Road SW
Tacoma, Washington 98498

Abstract

In 1996, to investigate harbor seal (*Phoca vitulina*) life history parameters, we captured harbor seals at Gertrude Island in south Puget Sound and at Boundary Bay in north Puget Sound. Blood samples from 116 seals were screened for presence of Phocine Distemper Virus (PDV), leptospirosis, and brucellosis. An additional 25 samples from 1994 and 59 samples collected in 1995 were analyzed for a total of 200 samples from south Puget Sound. Results were negative for PDV and leptospirosis. Twenty-four percent of the samples screened tested positive or suspected positive for *Brucella*. All 20 samples from north Puget Sound were negative for leptospirosis and brucellosis, but they were not tested for PDV.

In south Puget Sound, 55 seals were tagged and branded in October 1995, bringing the total of permanently marked seals in Puget Sound to 160. Sixty percent of these seals were resighted in the first year compared to 71% resighted from seals branded in 1994 and 85% resighted from seals branded in 1993.

The total number of harbor seals and the number of pups were counted at four sites in south Puget Sound. During the pupping season, approximately 500 seals used Gertrude Island (including about 110 pups), approximately 100 seals used Eagle Island (including about 10 pups), and approximately 400-500 seals used Woodard Bay (including more than 100 pups). No pups were observed at Commencement Bay which was used primarily by adult males and subadult seals. The first full-term pup was observed on Gertrude Island on 2 July 1996. Monthly mean counts at Gertrude Island varied from 194 to 548 seals; numbers peaked during the pupping season and were lowest during the winter. CVs of monthly mean counts were < 0.1.

Introduction

Life history theory predicts that parameters such as survival, recruitment, and female reproductive success differ between an increasing population and a stable, unharvested population. Changes in life history parameters have been proposed as a way to infer the status of a population relative to OSP. However, to date, an adequate time series of life history data has not been available to undertake such an analysis for harbor seals (*Phoca vitulina*). Information on life history parameters can be obtained from observational studies of permanently marked animals or from the collection of reproductive tracts and teeth of dead seals. Up to 700 harbor seals have been tagged in Puget Sound since the early 1980s and permanent marking of harbor seals in south Puget Sound began in 1993. To date, 160 harbor seals have been branded. Thirty-four percent of the branded seals are of known-age.

Survival of harbor seals can be affected by disease in the population such as Phocine Distemper Virus (PDV) which caused a massive seal die off in Europe in 1988. Reproductive failure can be caused by diseases such as leptospirosis or brucellosis. Screening for evidence of these diseases gives information on baseline health of the population and on elements which can affect life history parameters.

Originally, this project proposed to compare information on life history parameters obtained from observational studies in south Puget Sound with information on harbor seal life history parameters gathered from seals taken in the tribal harvest in Washington. However, no tribal harvest of harbor seals occurred in 1996.

Methods

In 1996, harbor seals were captured at three sites in south Puget Sound (Gertrude Island, Woodard Bay, and Eagle Island) and at one site in northern Puget Sound (Boundary Bay) using the beach seine technique developed by Jeffries et al. (1993), allowing large numbers of seals to be caught at one time. After the seals were removed from the capture net, they were placed in individual hoop nets where they remained until they were physically restrained for handling. Seals were tagged, weighed, measured, branded, had blood drawn for disease screening, and then were released. Age classes were defined as follows: lanugo, pup with lanugo coat present (premature); newborn, pup with umbilical cord present (1-4 days old); nursing, pup still dependant on female for nutrition (5 days-5 weeks); weaned, pup nutritionally independent (5 weeks to 1 year); yearling, 1 to 2 years old; subadult, 2-4 years old; and adult, 4+ years old.

Blood Screening

Ten to 30 ml of blood were taken from each animal. Blood was spun down and serum was screened for PDV, leptospirosis, and brucellosis. Testing for PDV was done by the U. S. Department of Agriculture (Plum Island, N.Y.), testing for leptospirosis and brucellosis was done by the Washington State Department of Agriculture (Olympia, WA), histopathology was done by NW ZooPath (Snohomish, WA), and general diagnostics were done by Phoenix Central Laboratory (Everett, WA). Heparinized whole blood was also taken and frozen. It is being held pending funding for future *Brucella* cultures from seals with positive *Brucella* titres.

Serum samples were tested for PDV by the microtitre neutralization test for antibodies to PDV. The sample was considered negative if the neutralization dilution was < 1:40. Leptospirosis was screened using microscopic agglutination tests for six different *Leptospira* antigens (*L. griptotyphosa, L. canicola, L. pomona, L. hardjo, L. icterohemorrhagiae, L. serjo*).

Results were considered negative if titres were < 1:400. *Brucella* was screened using *Brucella abortus* antigens on BAPA, Card, Rivanol, and Compliment Fixation tests. Titres were considered positive if the results were BAPA positive, Card positive, and Rivanol > +25. Titres were considered suspect if at least one test was positive.

Ground Counts

Harbor seals were counted at four sites in south Puget Sound (Gertrude Island, Eagle Island, Woodard Bay, and Commencement Bay). In all areas, seals were counted when maximum counts were expected. At Gertrude Island and Eagle Island the maximum number of seals are ashore during low tide. At Woodard Bay, the seals haul out on wooden floats which are available at all tides but maximum numbers appear in late afternoon. At Commencement Bay, seals haul out on log booms which are also available at all tides. Maximum numbers occur there when disturbance is low (early morning or after 4 pm). Counts were made of the total number of seals present; in addition, pups were counted when they were distinguishable from non-pups (from birth until about 3 months) between July and mid-October. Seals were counted at Gertrude and Eagle Islands at least 2-3 times per week during the breeding season and 2-3 times per month during the rest of the year, weather permitting. Seals were counted at Woodard and Commencement Bays at least twice a month during the breeding season and opportunistically during the rest of the year.

Brand and Tag Resighting

We concentrated our resighting effort of tagged and branded seals during the breeding season, but observations were made every month of the year. Observations at Gertrude Island were made with binoculars or 30-60X zoom telescope from points 60 m, 150 m, or 200 m from the seals. Identification of individuals at Gertrude Island was made using brand, tag number and color, unique color combinations of streamers attached to tags, or some combination of the three methods. Observations at the other sites were about 400 m from the seals; consequently, few individual identifications were made in these areas.

Results

Blood Screening

From 1994 to 1996, blood samples were taken from 200 individual seals during captures. Of these, 25 samples were collected in 1994, 59 samples in 1995, and 116 samples in 1996.

Phocine Distemper Virus: Serum from 24 adult and subadult harbor seals from south Puget Sound were tested for PDV. Results of all tests were negative (Table 1) although nearly one-half of the samples (10/24) had titre ratios of 1:20. Low titres like this may be an indication that the animal was exposed to PDV in the past or may be a cross reaction to another virus.

Leptospirosis: Serum from 200 harbor seals of all age classes were tested for antibodies to five *Leptospira* antigens. Results of all tests were negative (Table 2) although about one-third of the samples (70/200) had titre ratios of 1:100 against the *Leptospira griptotyphosa* antigen. Low titres may be an indication that the animal was exposed to Leptospirosis in the past or may be a cross reaction to another bacterium. None of the 20 samples from northern Puget Sound had titres against any *Leptospira* antigen.

Brucellosis: Serum from 200 seals of all age classes were tested by four methods for antibodies to *Brucella abortus*. Nearly one-fourth (48/200) of the samples had positive or suspect titres (Table 3). The age classes with the highest proportion of positive/suspect titres were yearlings (age 1-2 years) and subadults (age 2-4 years) with 68% (15/22) and 52% (14/27), respectively (Table 4). Age classes with the lowest percent of positive/suspect titres were adult females and nutritionally dependent pups with 0 and 3% (1/30), respectively (Table 4). None of the 20 samples from north Puget Sound had titres against *B. abortus* antigens (WDFW data).

Ground Counts

Harbor seals were counted at Gertrude Island, Eagle Island, Woodard Bay, and Commencement Bay throughout the year but observations were concentrated during the pupping season (July to October) when two-thirds of the counts were made. Seals were counted on more than 40 days at Gertrude and Eagle Islands and on 11 to 12 days at Woodard and Commencement Bays (Table 5). Up to 714 seals were seen at Gertrude Island and up to 608 seals at Woodard Bay where the maximum number of pups seen at each location was 133 and 147, respectively (Table 5). Because there is movement of seals between sites, these counts are not cumulative. During the pupping season, approximately 500 seals used Gertrude Island where about 110 pups were born, approximately 100 seals used Eagle Island where about 10 pups were born, and approximately 400-500 seals used Woodard Bay where more than 100 pups were born. No pups have been observed at Commencement Bay which is used primarily by adult male and subadult seals. The first pup was observed on Gertrude Island on 2 July 1996. Pupping probably begins at the end of June at Woodard Bay; 43 pups were present when observations began on 3 July. Monthly mean counts at Gertrude Island varied from 194 to 548 seals; numbers peaked during the pupping season and were lowest during the winter (Table 6). CVs of the monthly mean counts were < 0.1 (Table 6).

Brand and Tag Resighting

Between 9 and 25 October 1995, 55 harbor seals were branded on Gertrude Island (Table 7). In the first year after branding, 85% (33/39) of those branded in 1993, 71% (47/66) of those branded in 1994, and 60% (33/55) of the seals branded in 1995 were resighted (Table 7). As expected, the number of resightings was related to age/sex class (Tables 8, 9, 10). Of the adult males branded in 1995, 73% were seen in the following year compared to 60% of branded adult females, 59% of branded juveniles, and 46 % of branded pups (Table 10). During observations in the 1996 breeding season (2 July 1996 to 17 October 1996), 60% (97/160) of seals branded in 1993-95 were observed. Forty-four branded females (25 observed pregnant or with pups) and 53 branded males were seen. An additional 17 tagged (but not branded) females were seen pregnant or with pups. Individuals were resighted from 1 to 16 times. Two females tagged as subadults in 1993 gave birth for the first time in 1996. At least 3 tagged seals have given birth every year since 1993 and 75% of the branded females which gave birth in 1995 also gave birth in 1996.

Discussion

Blood Screening

Harbor seal blood serum was screened for several pathogens to determine the baseline health level of the population. Beginning in the late 1980s, WDFW screened seals at Gertrude Island in south Puget Sound for a variety of diseases, including San Miguel Sea Lion Virus, influenza, leptospirosis, and PDV. The results of all tests were negative (WDFW data). PDV has never been observed in Washington but there is concern about this disease because of the massive die offs of harbor seals, grey seals, and Baikal seals that have occurred on the Atlantic coast, in Europe, and Eurasia (Thompson et al. 1992). There is added concern because recent testing shows evidence of titres against PDV antigens in harbor seals in southeast Alaska and the Gulf of Alaska (Lewis 1995). Screening for leptospirosis and brucellosis is important because both diseases can cause reproductive failure which could affect harbor seal life history parameters. Testing for *Brucella* in seals was first conducted in the United Kingdom in 1991 as a result of the massive PDV die off in 1988. Positive cultures were found in several species of marine mammals in the North Sea, including harbor seals (Ross et al. 1996). Because of this, WDFW and NMML began testing for *Brucella* titres in 1994.

Phocine Distemper Virus: Because no evidence of PDV was found in the population, we recommend that screening for PDV occur once every 3 years unless there is an increase in unexplained harbor seal mortalities.

Leptospirosis: Some background testing for leptospirosis in harbor seals in Washington has been done in the past, but this was the first study of significant numbers of animals. Low levels of titres (< 1:400) were found in one-third of the seals tested. Most of the titres were against *L. gripptotyphosa* antigens. *L. gripptotyphosa* is the primary causative agent for leptospirosis in terrestrial wildlife. Clinical evidence of the disease has not yet presented itself, although positive titres have been found in moribund harbor seals in Washington State (WDFW data). Positive titres against *L. pomona* antigens and clinical manifestations of the disease have been found in other West Coast pinnipeds (California sea lions and northern fur seals). *L. pomona* is the primary causative agent for leptospirosis in domestic livestock. The recommendation is to continue testing for leptospirosis annually to monitor for any increases in the level of titres or increases in reproductive failure.

Brucellosis: This is the first time positive titres have been observed in West Coast pinnipeds. Positive cultures have been isolated from four dead harbor seals in south Puget Sound. Positive titres have also been observed in California sea lions and harbor porpoise from Washington State (WDFW data). Little is known of this disease in pinnipeds. Gertrude Island is an ideal location to describe this disease (i.e., pathology, increases in abortion rate, and decreases in natality) because the seals are of known reproductive history and observations are made frequently at this site. Annual screening is recommended as well as increased observation prior to full-term pupping.

Ground Counts

The total number of harbor seals and the number of harbor seal pups appears to be stable over the past 5 years in south Puget Sound (WDFW data). Since 1991, harbor seals have begun using Commencement Bay more frequently and in greater numbers. The log booms at Commencement Bay are part of a commercial operation; consequently, seals are disturbed there frequently during business hours. South Puget Sound is heavily used by recreational boaters who can cause some disturbance when seals are on land. However, the major haul out at Gertrude Island is within the purview of the State Prison at McNeil Island which keeps disturbance from boaters at a minimum. In the past, disturbance from coyotes at low tide has been noted periodically. A new form of disturbance at Gertrude Island was noted in 1996. At extreme low tides, deer cross from McNeil Island to Gertrude Island. The presence of deer on the beach or the sound of deer moving through the undergrowth causes the seals to move into the water.

Brand and Tag Resighting

The 1996 breeding season is the third year of resightings of branded harbor seals. There are some interesting differences among the years. The percent of animals resighted in the first year has declined from 85% for seals branded in 1993 to 60% for seals branded in 1995 (71% of seals branded in 1994 were resighted in the first year). When resights were analyzed according to age/sex categories, for seals branded in 1993 and 1994, the highest proportion of resights was of adult females and pups, with 80 to 100% of those age categories resighted in the first year; whereas 70 to 80% of juveniles and 50 % of adult males were resighted. In 1996, adult males were the most frequently resighted category (73%) and pups the least frequently resighted category (46%). The reason(s) for these differences is unknown and may be associated with interannual variation in haulout patterns which could be related to food availability, or to disturbance.

The number of marked animals and the history of those animals is increasing each year. Twelve branded females gave birth in 1995 and 25 branded females gave birth in 1996. Seventy-five percent of the branded females which pupped in 1995 also pupped in 1996. Three females marked as adults have been observed with pups in three consecutive years and two females branded as subadults in 1993 gave birth for the first time in 1996. As the number of branded animals of known-age and known-history increases, we will be able to answer questions about recruitment, natality, and survival of harbor seals in south Puget Sound.

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Table 1. Age and sex of harbor seals screened for Phocine Distemper Virus (PDV) in south Puget Sound, Washington by year, 1995-96 (see methods section for definition of age classes).

			Negative titres		Positive titres	
Year	Age class	n	Female	Male	Female	Male
1995	Subadult	10	5	5		
1996	Subadult	10	5	5		
	Adult	4		4		
Total		24	10	14	0	0

Table 2 . Age and sex of harbor seals screened for leptospirosis in Washington by year, 1994-96 (See methods section for definition of age classes).

			Negative titres (<1:400)		Positive titres (>1:400)	
Year	Age class	n	Female	Male	Female	Male
1994	Weaned pup	9	3	6		
	Yearling	2	1	1		
	Subadult	2	2			
	Adult	12	9	3		
Total		25	15	10	0	0
1995	Weaned pup	22	9	13		
	Yearling	5	3	2		
	Subadult	17	5	12		
	Adult	15	6	9		
Total		59	23	36	0	0
1996	Lanugo	3	1	2		
	Newborn	10	6	4		
	Nursing	17	8	9		
	Weaned pup	22	9	13		
	Yearling	15	9	6		
	Subadult	8	3	5		
	Adult	41	7	34		
Total		116	43	73	0	0
Summary	Total	200	81	119	0	0

Table 3. Age and sex of harbor seals screened for *Brucella* in south Puget Sound by year, 1994-96 (see methods for definition of age classes).

			Negative titres			Suspect titres			Positive titres		
Year	Age Class	n	Female	Male	Total	Female	Male	Total	Female	Male	Total
1994	Weaned pup	9	3	6	9						
	Yearling	2				1		1		1	1
	Subadult	2	2		2						
	Adult	12	9	3	12						
Total		25	14	9	23	1		1		1	1
1995	Weaned pup	22	7	11	18	2	2	4			
	Yearling	5				1		1	2	2	4
	Subadult	17	1	4	5	2	3	5	2	5	7
	Adult	15	6	4	10		5	5			
Total		59	14	19	33	5	10	15	4	7	11
1996	Lanugo	3	1	2	3						
	Newborn	10	6	4	10						
	Nursing	17	8	8	16		1	1			
	Weaned pup	22	6	11	17	2	2	4	1		1
	Yearling	15	5	2	7				4	4	8
	Subadult	8	3	3	6		2	2			
	Adult	41	7	30	37		1	1		3	3
Total		116	36	60	96	2	6	8	5	7	12

Table 4. Summary of harbor seals screened for *Brucella* in south Puget Sound, Washington, 1994-96 (see methods for definition of age classes).

			Negative titres			Suspect titres			Positive titres		
	Age Class	n	Female	Male	Total	Female	Male	Total	Female	Male	Total
	Lanugo	3	1	2	3						
	Newborn	10	6	4	10						
	Nursing	17	8	8	16		1	1			
	Weaned pup	53	16	28	44	4	4	8	1		1
	Yearling	22	5	2	7	2		2	6	7	13
	Subadult	27	6	7	13	2	5	7	2	5	7
	Adult	68	22	37	59		6	6		3	3
Total		200	64	88	152	8	16	24	9	15	24

Table 5. Summary of ground counts of harbor seals in south Puget Sound, 1996.

Area	Number of counts	Date of maximum total count	Maximum total count	Date of maximum pup count	Maximum pup count
Gertrude Island	46	16 Sep 96	714	03 Sep 96	133
Eagle Island	41	08 Nov 96	214	24 Sep 96	12
Woodard Bay	11	16 Aug 96	608	01 Aug 96	147
Commencement Bay	12	03 Oct 96	105		0

Table 6. Monthly mean counts of harbor seals at Gertrude Island, Washington, 1996 (counts affected by disturbance are not included).

Month	n	mean number of seals	SE	CV
January	3	212	19.2	0.09
February	1	194		
March	2	228	1.4	0.001
June	1	229		
July	4	319	17.5	0.05
August	7	408	9.4	0.02
September	7	548	11.9	0.02
November	3	302	24.1	0.08
December	1	287		

Table 7. Resightings of harbor seals branded 1993-95 in south Puget Sound. Resightings are from October 1 to September 30 each year.

BRANDED		RESIGHTED		
Year	Number	93/94	94/95	95/96
93	39	33	22	18
94	66	---	47	25
95	55	---	---	33
Total	160			

Table 8. Summary of resightings by age/class for harbor seals branded in 1993 in south Puget Sound. Resightings are from October 1 to September 30 each year.

AGE/CLASS	BRANDED	93/94	94/95	95/96
Adult male	1	0	0	0
Adult female	5	5	4	3
Juvenile	17	14	11	11
Pup	16	14 (includes 2 dead)	7	4

Table 9. Summary of resightings by age/class for harbor seals branded in 1994 in south Puget Sound. Resightings are from October 1 to September 30 each year.

AGE/CLASS	BRANDED	93/94	94/95	95/96
Adult male	17	---	9	3
Adult female	15	---	12	8
Juvenile	23	---	16	11
Pup	10	---	10 (includes 4 dead)	3

Table 10. Summary of resightings by age/class for harbor seals branded in 1995 in south Puget Sound. Resightings are from October 1 to September 30 each year.

AGE/CLASS	BRANDED	93/94	94/95	95/96
Adult male	15	---	---	11
Adult female	5	---	---	3
Juvenile	22	---	---	13
Pup	13	---	---	6

PINNIPED PREDATION ON ENDANGERED SALMONIDS IN WASHINGTON AND OREGON : HARBOR SEAL FOOD HABITS ON THE COLUMBIA RIVER

Patience Browne, Robert L. DeLong, Harriet R. Huber, and Jeffrey L. Laake

National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington 98115

Introduction

Increases in California sea lion (*Zalophus californianus*) and harbor seal (*Phoca vitulina*) populations in Washington and Oregon have coincided with decreases in wild salmon in these and other western states. Declines in salmonids have resulted in the recent listing of Columbia River spring and fall chinook, coastal Oregon coho, and Snake River sockeye salmon as endangered or threatened. In response to this issue, the National Marine Mammal Laboratory (NMML) began a project to quantify pinniped predation on salmonids in the Columbia River.

California sea lions, harbor seals, and Steller sea lions (*Eumetopias jubatus*) are present in the Columbia River and potentially prey on salmonids. California sea lions are present in the lower river system during spring and fall and haul out in the vicinity of a fish processing plant, but predation on salmon was not quantified because they potentially feed on the effluent which includes sockeye and chinook salmon carcasses. Steller sea lions are rarely seen in the Columbia River and only haul out near the river mouth. The impact of Steller sea lions on Columbia River salmon is assumed to be negligible. Harbor seals, the most abundant pinniped in the lower Columbia River, haul out in numbers exceeding 1,000 at Desdemona Sands, a sand bar that is accessible at low tide. Investigations of pinniped-salmonid interactions focused on harbor seals and their potential impact on the spring/summer and fall chinook salmon.

Methods

During 1994, 1995, and 1996, harbor seal scat samples were collected from Columbia River haul-out sites. Scats were collected intermittently during 1994 and 1995, and regular sampling began in 1996. From Desdemona Sands, we attempted to collect 50 harbor seal scats every 2 weeks at extreme low tides from March through August 1996, coinciding with spring and fall chinook salmon runs on the river. Scats were transported back to NMML and frozen until processing. At that time, scats were thawed, rinsed in nested sieves, and all hard parts were dried for later identification. Otoliths were identified to lowest possible taxon, sided left/right, enumerated, and length was measured. Other hard parts (teeth, vertebrae, skull bones, etc.) were identified to lowest possible taxon and a rough estimate of minimum number was estimated from unique structures when possible. Species-specific frequency of occurrence was computed as the number of scats containing a prey species divided by the total number of scats containing some identifiable hard parts. Frequency of occurrence was computed from identifications based on otoliths, bone, and from bone and otoliths combined.

Results

Due to inclement weather and low numbers of seals early in the collection period, our target sample size of 50 scats was not always attained (Table 1); however, we were able to collect 509 scats in 1996 in addition to 88 scats collected in 1994 and 280 in 1995 to characterize the diet of harbor seals for the lower Columbia River. Over 30 prey taxa have been identified, though, harbor seal diet can be characterized by about 10 common prey taxa having a frequency of occurrence greater than 5-10% (Table 2).

Salmonids were ranked tenth relative to other prey species in the harbor seal diet (Table 2) with frequency of occurrence at 11.4% for bone and otolith and 4.6% for otolith only. The overall frequency of occurrence is somewhat misleading because it did not adequately reflect temporal variability of salmonids in the Columbia River. When sampling periods were divided into spring (samples collected prior to 15 May), summer (samples collected between 16 May and 30 July), and fall (samples collected after 15 August), reflecting timing of chinook salmon runs, frequency based on bone and otolith increased to about 20% during the spring, decreased to about 7% during summer, and increased again in fall to about 18% (Table 3). Over 60% of scats were collected during the summer sampling period when the frequency of occurrence of juvenile and adult salmon in harbor seal diets was lowest (Table 3), decreasing the overall frequency of occurrence. Hard parts of juvenile salmonids (smolts) occurred more frequently than adult salmonids (including jacks) in scats except during the fall period (Table 3). Species identification of salmonid hard parts recovered from scat is ongoing. However, preliminary data indicated most salmonid otoliths were from smolts, and of those, 40% were chinook, 26.7% were steelhead/cutthroat, 23.3% were sockeye, and 10% were coho. Steelhead and cutthroat smolt otoliths were not distinguishable.

Discussion

Frequency of occurrence provides a relative measure of prey taxa but does not provide a measure of the impact of that predation upon the prey. Estimates of species-specific prey biomass consumed by harbor seals require additional data and assumptions. At present, we have not estimated harbor seal consumption of salmonids because previous biomass models do not account for prey remains other than otoliths. Before all of these data can be included in consumption estimates, we must modify traditional models.

Estimates of salmonid consumption from food habits data derived from scats require the following components (Table 4):

1) abundance: number, age and sex composition of harbor seals present in the Columbia River through time,
2) energetics: age- and sex-specific daily energetic requirements (kg/d), and
3) prey consumption: species-specific biomass estimates of prey consumed inferred from prey remains recovered from scats.

To estimate harbor seal abundance in the Columbia River, we have conducted aerial surveys of haul-out sites during low tide (WDFW unpubl. data). Counts must be corrected for the proportion of seals not hauled-out at the time of the survey. A correction factor of 1.53 to account for the proportion not hauled-out has been derived for harbor seals in the state of Washington (Huber 1995), though, this state-wide correction factor may not be appropriate for the Columbia River. In 1997, we radio-tagged and marked seals to estimate a site-specific correction factor from aerial surveys. When these data are analyzed, they will provide a more appropriate correction factor for this site. Age and sex-composition of harbor seals cannot be estimated from aerial surveys, so we assumed the following stable-age distribution: 26% 0-1 year (juvenile), 17% 1-4 year (sub-adult), 31% female greater than 4 years (adult), and 26% male greater than 4 years (adult; Bigg 1969, Pitcher and Calkins 1979).

The age- and sex-specific abundance of seals is required to adequately model the total energetic cost of maintenance for the Columbia River harbor seal population because energetic costs vary by sex and age. We are using the following daily maintenance requirements: for 0-1 year old seals, 1.80 kg/d; for 1-4 year old sub-adults, 2.88 kg/d; for adult females, 2.79 kg/d; and for adult males, 2.92 kg/d (Innes et al. 1987, Olesiuk 1993).

Total prey biomass required to maintain the Columbia River harbor seal population can be divided into species-specific prey biomass consumption estimates by apportioning total biomass required for maintenance of the Columbia River harbor seal population to prey taxa determined from scats. This requires estimating number and mass of prey consumed from hard parts. The number of prey consumed can be determined from the count of otoliths in the scat and the mass can be estimated from regressions of otolith length and standard length to mass (Harvey et al. in press). Otolith lengths must be corrected to account for reduction in length due to digestion. Species-specific corrections can be used where available (Harvey 1989) and in all other cases, otolith lengths can be corrected by an average correction factor. Estimated masses are averaged for the subsample of otoliths measured. Average mass of the prey taxa is multiplied by the minimum number of (left or right) otoliths from all scats to obtain the amount of biomass consumed for each prey species. Species-specific consumption can be estimated as relative biomass proportion of each prey species consumed, multiplied by the daily biomass requirement of the harbor seal population and number of days in the sampling period (Table 4). Clearly, temporal variability in prey selection will require stratifying the estimates by season (Table 3).

Estimates of prey consumption include several assumptions that may bias results if violated. In particular, we will have to assume:
1) theoretical life-table sex- and age-structure represents the Columbia River harbor seals,
2) estimates of energetic costs are applicable, and
3) otoliths recovered from scats are representative of the prey consumed.
Clearly, each of these will be violated to some degree and we are attempting to minimize assumptions to reduce potential biases.

Using life-tables to predict sex- and age-composition could be completely inaccurate and we have no reason to believe that harbor seals on the Columbia River during the breeding season have a stable-age distribution. Though steadily increasing since 1978, aerial surveys conducted during 1996 indicate a June maximum of only 105 pups to 886 adult harbor seals (WDFW unpubl. data). This proportion of pups is lower than those reported for other coastal estuaries. To better estimate biomass, age and sex composition of harbor seals on the Columbia River during summer we would need to capture, sex, and measure seals. Another alternative is to use a relative sex-age structure from a life table for non-juveniles and proportion of pups observed during aerial surveys to estimate the proportion of juveniles in the population. This should reduce bias because most of the difference in energetic costs are between juveniles and non-juveniles.

The model assumes a constant energetic requirement for the seal and does not account for such activities as lactation and mating. Also, each prey species is assumed to provide a constant amount of energy (kcal/kg). Differential energetic values of adult versus juvenile fishes and gravid and non-gravid fishes are not estimated.

Before reliable estimates can be generated, several pieces of data are needed to better model harbor seal biomass consumption. Regressions of otolith size to body mass need to be generated for all species of salmonids consumed by harbor seals on the Columbia River. Although a few relationships between otolith length and fish mass of salmonids are published, these morphometric regressions have not been calculated for all species of salmonids. In addition, published regressions do not include sub-adult size classes. Regressions of otolith length on fish standard length and fish standard length to fish mass calculated for adult fishes do not work well for juvenile size classes.

Traditional marine mammal food habits techniques have relied on otoliths for enumeration and identification of prey species. Results of this study indicate that using only otoliths may underestimate frequency of occurrence of most prey species by about two to three times, but some species such as American shad, *Sebastes* spp., and gunnel may be underestimated by between 10 and 20 times (Table 2). While these data illustrate the necessity of incorporating hard parts other than otoliths into food habits analyses, how to include bone into species-specific biomass is unclear. Biomass estimates require an estimate of prey mass and it is difficult to determine prey size from hard parts other than otoliths. For example, the most frequently recovered hard parts for salmonids are teeth and gillrakers and these parts are difficult to categorize by size. Harbor seals often feed on juvenile fishes seasonally inhabiting estuarine systems. However, due to the small size, juvenile otoliths may be completely digested and not recovered from scat. Mean mass of a prey taxon may be based on measurements of adult otoliths, but then applied to the minimum number of individual prey consumed based on bone and otoliths that represent juveniles, and therefore overestimate the total biomass. Also, larger fish may have a greater probability of being recovered (i.e., bones from one herring may be recovered from only one scat, but bones from one adult salmon may be recovered from several scats, increasing the probability of recovering salmon bone).

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Table 1. Sampling date and number of harbor seal scats collected from the Columbia River haul out from June 1994 through August 1996.

Sample Date	# Samples Collected
6/23/94	33
7/10/94	50
3/5/95	13
5/3/95	30
5/18/95	27
5/19/95	35
6/14/95	33
6/15/95	25
6/16/95	24
6/28/95	35
6/29/95	44
7/14/95	34
3/14/96	29
3/21/96	11
4/10/96	47
4/18/96	1
5/2/96	32
5/3/96	2
5/8/96	12
5/30/96	36
5/31/96	18
6/18/96	24
6/19/96	55
7/2/96	55
7/24/96	51
8/15/96	43
8/16/96	35
8/29/96	60

Table 2. Frequency of occurrence of prey identified to the lowest possible taxon for 877 harbor seal scats collected from Desdemona Sands between 23 June 1994 and 29 August 1996. Frequency of occurrence was calculated by dividing the number of scats containing a particular prey taxa (the number in italics) by the total number of scats with any hardpart recovered (877). Minimum *n* is the minimum number of individuals of a prey taxon based on bone structures, the maximum number of left or right otoliths, or the greater of the two. Frequency of occurrence of bone and otoliths of prey were ranked.

Prey	BONE		OTOLITHS		BONE AND OTOLITHS		
	FO%	minimum *n*	FO%	minimum *n*	FO%	minimum *n*	RANKS
herring	43.6 *382*	459	17.8 *156*	356	45.7 *401*	654	1
staghorn sculpin	25.1 *220*	240	13.3 *117*	320	27.8 *244*	456	2
Osmeriid spp.	14.3 *125*	434	12.8 *112*	103	20.2 *177*	499	3
starry flounder	17.4 *153*	156	7.5 *66*	145	19.3 *169*	248	4
river lamprey					17.9 *157*	159	5
northern anchovy	14.5 *127*	133	7.1 *62*	279	15.7 *138*	223	6
shiner surfperch	13.1 *115*	121	6.3 *55*	205	15.2 *133*	281	7
Pacific tomcod	10.8 *95*	95	4.4 *39*	69	12.8 *112*	142	8
American shad	11.7 *103*	103	1.3 *11*	10	12.4 *109*	109	9
Salmonid	10.1 *89*	93	4.6 *40*	101	11.4 *100*	161	10
Salmonid juvenile	6.2 *54*	54	3.6 *32*	91	7.2 *63*	122	
Salmonid adult	4.2 *37*	37	1.0 *9*	11	4.4 *38*	39	
Sebastes spp.	9.5 *83*	83	0.9 *8*	11	9.6 *84*	88	11
gunnel	9.4 *82*	84	0.2 *2*	2	9.4 *82*	85	12

Prey	BONE		OTOLITHS		BONE AND OTOLITHS		
	FO%	minimum *n*	FO%	minimum *n*	FO%	minimum *n*	RANKS
sandlance	6.8 *60*	60	2.9 *25*	48	8.0 *70*	93	**13**
Pacific lamprey					7.1 *62*	73	**14**
rex sole	5.7 *50*	51	2.5 *22*	68	6.2 *54*	103	**15**
peamouth	5.4 *47*	47	2.5 *22*	47	5.8 *51*	74	**16**
hake	3.1 *27*	27	0.8 *7*	9	3.4 *30*	38	**17**
dover sole	2.1 *18*	18	1.4 *12*	25	2.5 *22*	37	**18**
Pleuronectid spp.			2.3 *20*	20			**19**
English sole	1.3 *11*	11	1.3 *11*	18	2.2 *19*	26	**20**
eulachon	1.7 *15*	15	1.5 *13*	21	2.2 *19*	26	**21**
speckled sanddab	0.1 *1*	1	0.9 *8*	11	1.0 *9*	12	**22.5**
squid					1.0 *9*	9	**22.5**
octopus					0.6 *5*	7	**24**
slender sole			0.5 *4*	5			**25**
plainfin midshipman			0.1 *1*	1			**26**
unidentified fish	11.6 *102*	102	8 *70*	72			

Table 3. Frequency of occurrence of salmonids in harbor seal scats collected from Desdemona Sands between 26 July 1994 and 29 August 1996. Frequency of occurrence was calculated by dividing the number of scats containing salmonid hard parts (the number in italics) by the total number of scats containing hardparts (877). Min *n* is the minimum number of individuals represented by maximum number left of right otoliths, bone structures, or the greater of the two. Data were analyzed for three time periods, corresponding to timing of salmon runs on the Columbia River: Period 1 (samples collected before May 15), Period 2 (samples collected between 16 May and 15 August), and Period 3 (samples collected after 15 August). Juvenile salmonids (smolts) and adult salmonids (including jacks) were considered separately and together.

	PERIOD 1 *n* = 176		PERIOD 2 *n* = 563		PERIOD 3 *n* = 138	
	FO%	min *n*	FO%	min *n*	FO%	min *n*
Salmonid (juvenile)						
bone	15.3	27	3.5	20	5.0	7
	27		*20*		*7*	
otoliths	56.8	26	2.7	55	3.6	15
	12		*15*		*5*	
bone & otoliths	7.16	45	4.1	67	7.2	10
	31		*23*		*10*	
Salmonid (adult)						
bone	3.4	6	2.7	15	11.5	16
	6		*15*		*16*	
otolith	0.6	1	0.9	5	2.9	5
	1		*4*		*4*	
bone & otoliths	3.4	6	2.8	16	11.6	17
	6		*16*		*16*	
Salmonid (all)						
bone & otoliths	20.5	51	6.9	83	18.1	27
	36		*39*		*25*	

Table 4. Components and equations for computation of consumption estimates.

Component	Equation	Symbols
Total population size (N)	$N = \dfrac{\bar{c}}{p}$	$\bar{c}$ = average count of seals hauled-out p = average proportion of seals hauled-out
Sex- and age-specific size (N_a)	$N_a = N p_a$	a = 1 - juvenile seals (0-1 year old) a = 2 - sub-adult seals (1-4 years old) a = 3 - adult female seals a = 4 - adult male seals p_a = proportion of population in the a[th] sex/age class
Daily consumption requirement (B)	$B = \sum_{a=1}^{4} C_a N_a$	C_a = daily energetic requirement (kg/d) for a[th] sex/age class a = 1, 1.80 kg/d, a=2, 2.88 kg/d, a=3, 2.79 kg/d, a=4, 2.92 kg/d
Average prey mass estimates for species j ($\bar{M}_j$)	$\hat{L}_{ij} = \alpha_j + \beta_j O_{ij}$ $\hat{M}_{ij} = \alpha_j + \beta_j \hat{L}_{ij}^{3}$ $\bar{M}_j = \dfrac{\sum_{i=1}^{n_j^*} \hat{M}_{ij}}{n_j^*}$	α_j and β_j are generic species-specific regression coefficients $\hat{L}_{ij}$ *and* $\hat{M}_{ij}$ = estimated length and mass for i[th] otolith n_j^* = number of otoliths sub-sampled from n_j otoliths recovered from scats
Relative proportion of prey biomass for species j (p_j)	$p_j = \dfrac{\bar{M}_j n_j}{\sum_{i=1}^{s} \bar{M}_i n_i}$	n_j = number of otoliths recovered from scats s = number of prey species identified in scats
Biomass of species j consumed (B_j)	$B_j = B p_j D$	D = number of days

ABUNDANCE AND DISTRIBUTION OF HARBOR SEALS (*Phoca vitulina richardsi*) ALONG THE SOUTH SIDE OF THE ALASKA PENINSULA, SHUMIGAN ISLANDS, COOK INLET, KENAI PENINSULA AND THE KODIAK ARCHIPELAGO IN 1996

David E. Withrow and Thomas R. Loughlin

National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington 98115

Abstract

Minimum population estimates were obtained for harbor seals, *Phoca vitulina richardsi*, in the Gulf of Alaska region along the south side of the Alaska Peninsula, Shumigan Islands, Cook Inlet, Kenai Peninsula and the Kodiak Archipelago during August and September 1996. The mean number of seals counted was 10,595 with a 95% confidence interval between 9,993 and 11,197. The CV of the mean was equal to 2.9%. This represents an increase of 4,259 seals when compared to the mean count from similar surveys in 1992. However, at least 1,675 seals were counted in areas not described in 1992. Aerial survey conditions were exceptionally good in 1996, unlike 1992. At selected major sites (>100 seals) from all areas surveyed in both years, 11 of 20 sites increased and 7 decreased. The overall trend was positive. Approximately 846 more seals (18%) were counted in 1996 at these 20 sites. Seal counts between 1992 and 1996 were nearly identical in the fringe areas, but increased toward the center of the range, the Kodiak Archipelago. By far the largest increase occurred at Tugidak Island, which increased from 770 seals in 1992 to 1,345 in 1996. Seal counts at Tugidak Island, even though increasing, still represent an 80% decline over counts made in 1976.

Introduction

Declines in harbor seal *(Phoca vitulina richardsi)*, abundance have been observed in several locations throughout Alaska (e.g., Pitcher 1990). Recent amendments to the Marine Mammal Protection Act (April 30, 1994, Public Law 103-238) require the Secretary of Commerce to reduce the overall mortality and serious injury to zero marine mammals caught incidental to commercial fisheries by April of 2001. In order to evaluate the status of incidentally caught marine mammals, certain key parameters are required for each stock. These parameters include an estimate of: population size, its variance, and current takes by commercial fisheries and subsistence hunters. The long-term objective of this study is to provide an estimate of the number of harbor seals throughout Alaska and, where possible, determine current population trends.

In Alaska, harbor seals range from southeastern Alaska in the south to north of Bristol Bay (to about 59°N; Frost et al. 1982). We have arbitrarily sub-divided the state into four regions for census purposes. These are: southeastern Alaska, the Gulf of Alaska (from Prince William

Sound to the Shumigan Islands), the Aleutian Islands, and the north side of the Alaska Peninsula including Bristol Bay. These regions roughly follow the putative stock management areas, but logistical considerations were the primary factor used for this delineation. The National Marine Mammal Laboratory (NMML), with funding from the NMFS Office of Protected Resources, has censused each of these four regions once between 1991 and 1994 (Loughlin 1992 [Bristol Bay, Prince William Sound, and Copper River Delta], Loughlin 1993 [Gulf of Alaska and Prince William Sound], Loughlin 1994 [Southeastern Alaska], and Withrow and Loughlin 1995 [Aleutian Islands]). In order to provide current population estimates with low coefficients of variation (CVs) and estimates of population trend, especially in areas of decline and neighboring locations, NMML began Phase II, a re-census and evaluation of each of the four regions, in 1995. The north side of the Alaska Peninsula and Bristol Bay was surveyed in 1995 (Withrow and Loughlin 1996). This paper describes the results of our census efforts in the Gulf of Alaska region, including the south side of the Alaska Peninsula, Shumigan Islands, Cook Inlet, Kenai Peninsula, and the Kodiak Archipelago in 1996. Prince William Sound was surveyed in 1996 by the Alaska Department of Fish and Game and by John Burns (Living Resources, Inc.). NMML also censused the Copper River Delta, Middleton Island, and Kayak Island in 1996 and results are presented in this paper.

Methods

Study Area

The study in 1996 consisted of seven aerial surveys. The first area was censused by M. Beeson along the south side of the Alaska Peninsula and the Shumigan Islands from Cold Bay to Kupreanof Peninsula (from 25 August to 1 September; Fig. 1, see Table 1 for affiliations). L. Lowry censused the south side of the Alaska Peninsula from Chignik Bay to Cape Douglas Reef including Semidi and Chirikof Islands (25-30 August; Fig. 2). K. Wynne and P. Olesiuk surveyed the entire Kodiak Archipelago. P. Olesiuk surveyed Afognak Island and the northern part of Kodiak Island (25 August to 3 September; Fig. 3). K. Wynne censused the south side of Kodiak Island including Tugidak and Sitkanak Islands (28 August to 3 September; Fig. 3). B. Mahoney surveyed the north side of Cook Inlet from Anchorage to Cape Douglas (25 August to 2 September; Fig. 4). M. Payne surveyed the Kenai Peninsula (26 August to 2 September; Fig. 4). J. Cesarone and D. Withrow surveyed the Copper River Delta, Middleton Island and Kayak Island (27 August to 1 September; Fig. 5). Table 1 lists the individuals, dates, and aircraft used to survey each area.

Survey Methods

Fixed-wing aircraft were used to photograph harbor seals while they were on land during their fall molt; this is the optimal period to estimate abundance because it is when the greatest number of harbor seals spend the greatest amount of time hauled out (Pitcher and Calkins 1979; Calambokidis et al. 1987). At locations that are affected by tides, harbor seals haul out in greatest numbers at and around the time of low tide. Aerial surveys were arranged and timed such that terrestrial haulout sites were flown within 2 hrs on either side of low tide, when available daylight and weather permitted. Initially, the entire coastline was flown to determine the location of any new harbor seal haulout sites as well as all known haulout sites. Subsequently, four to seven repetitive photographic counts were conducted for each major haulout site within each study area over the 2 week survey period. We have determined that four or more repetitive surveys are necessary to obtain estimates of coefficient of variation (CV; standard deviation of the counts divided by the mean count) less than 30%. Past surveys, where at least four or five replicates were flown, have proven to be an effective way of counting the maximum number of animals (Loughlin 1992, 1993; Pitcher 1989, 1990; Withrow and Loughlin 1995).

Harbor seals on land or in the water adjacent to the haulout sites were photographed with 35 mm cameras with a 70-210 mm or 35-135 mm zoom lens using ASA 400 color slide film. Transparencies were later projected onto a white background and the number of seals counted. In most cases, two counters scored the number of seals on the photographs for each area for each survey day and the arithmetic mean was calculated for each site. The largest arithmetic mean obtained for each area was used as the minimum population estimate. Visual estimates of abundance were also recorded at the time of the survey. Small groups of seals (generally less than 10) were counted as the plane passed by (no photographs were taken), while larger groups were circled and photographed.

Most surveys were flown at a survey altitude between 100 and 300 m (wind permitting) at about 90 knots. Surveys were staged out of the following communities: Cold Bay, Larsen Bay, Kodiak, Anchorage, and Cordova.

Data Analysis

The maximum number of animals counted on one day for each site was accepted as that site's minimum number of seals over the survey period. The maximum number for each site did not occur on the same day, resulting in the possible double counting of some animals if they moved from one major area to another. The number of seals moving between areas was assumed to be small considering each area's large geographic size.

The mean and standard deviation (SD) of the mean were calculated for each area. Estimates of the number of animals hauled out during the survey were calculated by summing the mean number of harbor seals ashore at each site. The CVs were calculated for all sites with two or more counts. The SD for sites with only one count was estimated based on the maximum of the calculated CVs of the mean (1.0 used in 1996) multiplied by the count for that site. The variance of the total count for each area was calculated as the sum of the individual variances and the SD of the mean count as the square root of that variance. This method of estimating the expected total and its variance assumes that there is no migration between areas and that there was no trend in the number of animals ashore over the survey period. The assumption that seals did not move between areas may not be valid (as mentioned above) and a small number of seals may have been counted twice. All areas that could be surveyed were censused, given weather and safety constraints.

The exact location of each seal haulout was recorded and given an individual site number (Table 2).

Results

Area 1 (South side of the Alaska Peninsula and the Shumigan Islands from Cold Bay to Kupreanof Peninsula)

This area contained 46 individual sites. One to six replicate counts were recorded for each site during the 8 day survey window. The maximum count of 2,130 harbor seals was obtained by combining the maximum count for each area regardless of day censused. The sum of means was $\bar{x}$ = 1,348 harbor seals (SD = 68.29), with a CV = 5.06% (Table 3).

Area 2 (South side of the Alaska Peninsula from Chignik Bay to Cape Douglas Reef including Semidi Islands and Chirikof Islands)

This area contained 56 individual sites. One to five replicate counts were recorded for each site during the 6 day survey window. The maximum count of 2,848 harbor seals was obtained by combining the maximum count for each area regardless of day censused. The sum of means was $\bar{x}$ = 1,852 harbor seals (SD = 85.23), with a CV = 4.60% (Table 4).

Area 3 (Kodiak Archipelago)

This area contained 79 individual sites. One to seven replicate counts were recorded for each site during the 10 day survey window. The maximum count of 6,473 harbor seals was obtained by combining the maximum count for each area regardless of day censused. The sum of means was $\bar{x}$ = 4,437 harbor seals (SD = 156.43), with a CV = 3.53% (Table 5).

Area 4 (North side of Cook Inlet from Anchorage to Cape Douglas)

This area contained 44 individual sites. One to seven replicate counts were recorded for each site during the 9 day survey window. The maximum count of 3,342 harbor seals was obtained by combining the maximum count for each area regardless of day censused. The sum of means was $\bar{x}$ = 2,244 harbor seals (SD = 234.68), with a CV = 10.46% (Table 6).

Area 5 (Kenai Peninsula)

This area contained 16 individual sites. One to seven replicate counts were recorded for each site during the 7 day survey window. The maximum count of 1,008 harbor seals was obtained by combining the maximum count for each area regardless of day censused. The sum of means was $\bar{x}$ = 713 harbor seals (SD = 51.33), with a CV = 7.19% (Table 7).

Estimated Population Size for the Gulf of Alaska from Unimak Pass to (but not including) Prince William Sound (Areas 1-5 Combined)

The entire region from Unimak Pass to the Kenai Peninsula and the Kodiak Archipelago (Areas 1-5) contained 241 individual sites. One to seven replicate counts were recorded for each site during the 10 day survey window. The maximum count of 16,059 harbor seals was obtained by combining the maximum count for each area regardless of day censused. The sum of means was $\bar{x}$ = 10,595 harbor seals (SD = 306.77), with a CV = 2.90% (Table 8).

1996 and 1992 Comparisons

Routes flown in 1996 were similar, but not exactly the same to those flown in 1992. For example, Chirikof Island was surveyed as part of Area 2 in 1996, but was part of Area 3 in 1992. In order to compare results between 1996 and 1992, the 1992 data were put into the same area categories as 1996 and recalculated. The results appear in Table 9. Similar numbers of seals were seen between 1992 and 1996 in Area 1 (1,419 and 1,348) and Area 5 (695 and 713). In Areas 2 and 4, there were 796 and 1,139 more seals detected in 1996 than in 1992, respectively. In Area 3, the Kodiak Archipelago, 2,376 more seals were counted in 1996 than in 1992. Overall, using mean values, 4,259 more seals were detected in 1996 (10,595) than in 1992 (6,336).

Twenty "major" sites (those with more than 100 seals in either 1992 or 1996) were identified (Table 10). Seven of these sites had fewer seals in 1996 than in 1992 and 11 sites were greater. There was a net increase of 846 in the number of seals detected at these 20 sites from 1992 (3,753) to 1996 (4,599).

Counts from the surveys of the Copper River Delta, Middleton Island and Kayak Island are presented in Table 11. They will be discussed in another paper, including data from other surveys of Prince William Sound conducted by the Alaska Department of Fish & Game and Exxon during the same period.

Discussion

The 1996 harbor seal census surveys were conducted in a similar manner to those of 1992 (Loughlin 1993). We used six aircraft, each with an experienced observer, to cover nearly the same routes used in 1992, and one additional aircraft for the Copper River. Two major changes were made. We decided to position a twin-engine Aero-Commander on Kodiak Island (Larsen Bay) instead of a single-engine plane based in King Salmon. In 1992, weather often prevented the single engine plane from surveying the entire area. The weather in 1996 was exceptional. Excellent survey conditions existed during the entire survey period. Additional survey hours were added to several aerial survey contracts to take advantage of the unusually good conditions. Low tides were primarily in the morning, but since the weather was good, observers were often able to survey during both morning and evening tides, thus surveying more sites at optimal tides. In 1992, the low tides occurred very early in the morning, often before daylight, which limited some survey effort to less than ideal tidal states.

For Area 1 (south side Alaska Peninsula and Shumigan Islands) we found 1,348 seals in 1996 and 1,419 seals in 1992 (Tables 3 and 9), essentially no change. At the extreme other end of the Gulf of Alaska, Area 5 (Kenai Peninsula) we also noticed no difference between 1996 with 713 seals and 1992 with 695 seals (Tables 7 and 9). In all other areas the 1996 counts were higher than in 1992, particularly near the center of the survey area (i.e., the Kodiak Archipelago).

In Area 2 (south side Alaska Peninsula including the Semidi Islands and Chirikof Islands), counts were up 796 in 1996 to 1,852 seals, almost 75% more when compared to the 1992 estimate of 1,056 seals (Tables 4 and 9). In 1996, the area surveyed continued east to Cape Douglas. Although the 1992 surveys were reported to have surveyed to Cape Douglas, the furthest haulout listed to the east was Katmai Bay, approximately 128 km (69 nautical miles) from

Cape Douglas. In this area between Katmai Bay and Cape Douglas, Lowry found 553 seals in 1996, which accounts for 52% of the 75% mentioned above.

In Area 4 (north side of Cook Inlet to Shaw Island) 1,139 more seals were located in 1996 (2,244) than in 1992 (1,105)(Tables 6 and 9). Area coverage appears to be similar between years, but in 1996, 445 seals were located by Mahoney at four sites which do not appear to have been surveyed in 1992 (E. of Akumwarik Bay, McNeil Head, E. of Amakedori, and Laney Reef).

In Area 3 (the Kodiak Archipelago) 2,376 more seals were found in 1996 (4,432) than in 1992 (2,061)(Tables 5 and 9). New sites were discovered by both observers in this area which apparently were not surveyed in 1992. More sites were recorded by all observers in all areas, but this is difficult to quantify since observers during the 1996 surveys subdivided sites into finer increments than did observers in 1992. Wynne found seals (~ 392) along the southern side of Kodiak Island in areas not recorded previously (e.g., Olga Bay, Sukhoi River, Sulua Bay, Alitak Reef area and Kiliuda Bay, Shearwater Bay, Barnabas Rocks area). Olesiuk also discovered seals at new sites (~ 285 at Spiridon Bay, Zachar Bay, Malka Bay and at the extreme northeast corner of Afognak Island. By far the biggest difference was found at Tugidak Island. In 1992, the sum of the mean counts was 770 seals, whereas in 1996, the sum of mean counts was 1,345 seals (Table 10), an increase of 575 seals.

At Tugidak Island, Pitcher (1990) documented an 85% decline from mean counts in 1976 (6,919 seals) to 1988 (1,014 seals). Our 1992 aerial estimate was 770 seals, a decline of 89% from Pitcher's 1976 mean count. Our 1996 estimate of 1,345 seals represents a decline from 1976 of 80%. An increase in counts also occurred at 11 of 20 "major" sites. In 1992, 3,753 seals were counted at these selected sites, and 4,599 were counted in 1996. This is an increase of 846 seals or approximately 18%.

Reasons for the Increase

There are several possible reasons for the increase in our counts of seals between the 1992 and 1996 census surveys. The first is that survey conditions were excellent in 1996. When survey conditions are good, more replicate flights are possible, image quality of the photographs are better, and the survey logistics are easier, all of which lead to improved data quality. More seals haul out when winds and rain are not heavy (Withrow and Loughlin 1996). In all survey areas, the standard deviation (SD), coefficient of variation (CV), and 95% confidence intervals (CI) (Table 9) were improved in 1996 over 1992.

At least 1,675 seals were counted in areas not described in Loughlin (1992). Since it is not possible to reconstruct the 1992 survey[1], it is unclear whether these areas were observed and no seals were found, or if they were not surveyed. In addition to the factors mentioned above, we believe the actual number of seals has increased. Comparing important sites (> 100 seals) from all areas, we observed an increase of 846 seals, or approximately 18% more between 1992 and 1996.

For Areas 2 and 4, approximately 70% and 40%, respectively, of the observed increase in seals numbers between 1992 and 1996 can be explained by counts from areas not described in

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[1]The database contains only sites in which animals were present. As a result, although survey protocol states that all coastline is to be searched, it is not possible to determine if sites in which no animals were counted in 1992 were actually surveyed.

1992. The remaining percentage differences (i.e. 30% and 60%) can be explained by: an actual increase in seals numbers (perhaps 20%), weather, tide, time of day and other unknown factors controlling seal haul out behavior and census accuracy.

For Area 3, at least 30% of the increase can be explained by seals found in new areas not described and perhaps not censused in 1992 which leaves 70% (or less) to be explained by an actual increase in the number of seals and other factors.

We suggest that the mean estimate of 10,595 be used to represent the number of seals in the Gulf of Alaska from Unimak Pass to (and including) the Kenai Peninsula (Areas 1-5). The overall 95% CI ranges from 9,993 to 11,197, SD equal to 306.77 and a CV of 2.90% (Table 8).

Acknowledgments

This report is a summary of surveys conducted by the people listed in Table 1 and who are gratefully acknowledged for their time and effort. Most observers counted their own slides and Jack Cesarone recounted all slides from all observers and input data from field notes into a computerized database. Anne York provided analytical advice. This paper was improved by comments from Kate Wynne and Peter Olesiuk.

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Table 1. Survey dates, locations, observers, and aircrafts used during the 1996 harbor seal census surveys.

Survey dates and location				
Area No.	Location	Observer\ affiliation	Dates	Platform
1	**South Side Alaska Peninsula** (Cold Bay to Kupreanof Peninsula + Shumigan Islands)	**Marilyn Beeson** CDF&G	8/25 - 9/1 1996	Aero Commander
2	**South Side Alaska Peninsula** (Chignik Bay to Cape Douglas + Semidi Islands and Chirikof Islands)	**Lloyd Lowry** ADF&G	8/25 - 8/30 1996	Aero Commander
3	**Kodiak Archipelago** (Afognak and N. Kodiak Islands)	**Peter Olesiuk** DFO	8/25 - 9/3 1996	Cessna 206 (floats)
3	**Kodiak Archipelago** (S. Kodiak & Tugidak Islands)	**Kate Wynne** UA/SG	8/28 - 9/3 1996	Cessna 206 (floats)
4	**North Side Cook Inlet** (Anchorage to Cape Douglas)	**Barbara Mahoney** NMFS/A	8/25 - 9/2 1996	Cessna 206 (floats)
5	**Kenai Peninsula**	**Mike Payne** NMFS/DC	8/26 - 9/2 1996	Cessna 185 (floats)
	Copper River Delta (+ Middleton and Kayak Islands)	**Jack Cesarone** **Dave Withrow** NMFS/NMML	8/27 - 9/3 1996	Cessna 185 (floats)

Affiliations:

ADF&G	=	**Alaska Department of Fish and Game**
CDF&G	=	**California Department of Fish and Game**
DFO	=	**Canadian Department of Fisheries & Oceans**
NMFS/A	=	**National Marine Fisheries Service** (Anchorage Area Office)
NMFS/DC	=	**National Marine Fisheries Service** (Washington D.C., Office of Protected Resources)
NMFS/NMML	=	**National Marine Fisheries Service/ National Marine Mammal Laboratory**
UA/SG	=	**University of Alaska, Sea Grant**

Table 2. **Site location number and name, latitude, longitude (in decimal degrees), area number, and observer.**

Location Number	Location Name	Latitude	Longitude	Area	Observer
1	Cape Lazaref	54.6000	163.5833	1	Beeson
2	Bird I.	54.6667	163.3000	1	Beeson
3	Sanak I.	54.5000	162.8667	1	Beeson
4	Sankin I.	54.8000	163.2667	1	Beeson
5	Morahovoi Bay	55.1094	163.1464	1	Beeson
6	S. of Cold Bay	55.2556	162.6889	1	Beeson
7	Cold Bay	55.2667	162.6333	1	Beeson
8	Sozavarika I.	54.8583	162.5167	1	Beeson
9	Let I.	54.8417	162.4500	1	Beeson
10	S of Deer I.	54.8250	162.3500	1	Beeson
11	N.E. of Hunt I.	54.7947	162.1797	1	Beeson
12	Sandman I.	54.7917	162.1750	1	Beeson
13	Patton I.	54.9011	162.1306	1	Beeson
14	Buyan Is.	54.9000	162.1167	1	Beeson
15	Sushilnoi I.	54.8667	161.8583	1	Beeson
16	Sarana I.	54.9667	161.9167	1	Beeson
17	Volcano Bay	55.1819	162.0011	1	Beeson
18	Iliasik (Outer)	55.0167	161.8667	1	Beeson
19	Dolgoi I. S.	55.0906	161.8231	1	Beeson
20	Dolgoi I. N.	55.1500	161.7083	1	Beeson
21	Paulof Bay S.	55.4000	161.6167	1	Beeson
22	Paulof Bay	55.4833	161.6167	1	Beeson
23	Paulof Bay N.	55.5478	161.5892	1	Beeson
24	Ukolnoi I. S.	55.2281	161.5378	1	Beeson
25	Ukolnoi I. N.	55.2608	161.5542	1	Beeson
26	Wosnesenski I. W.	55.2256	161.4536	1	Beeson
27	Wosnesenski I. E.	55.2239	161.3472	1	Beeson
28	Kennoys I.	55.1564	161.1061	1	Beeson
29	Seal Cape	55.3522	161.2222	1	Beeson
30	Unaga I. N.	55.3250	160.6500	1	Beeson
31	Unaga I. S.	55.1667	160.4833	1	Beeson
32	Popov I.	55.2844	160.4278	1	Beeson
33	Popov I. S.	55.2586	160.3786	1	Beeson
34	Turner I. W.	55.0469	159.8589	1	Beeson
35	Bird I. N. W.	54.8214	159.7994	1	Beeson
36	Simonof I. S.	54.8667	159.2583	1	Beeson
37	Simonof I. N.	54.9000	159.3333	1	Beeson
38	Koniuji I.	55.0478	159.6311	1	Beeson
39	Nagai I. N.E.	55.2214	159.8831	1	Beeson
40	Nagai I.	55.2397	159.9406	1	Beeson
41	Guillemot I.	55.5500	160.3667	1	Beeson
42	Doreno Bay	55.6372	160.2694	1	Beeson
43	Orzinski Bay	55.7000	160.0533	1	Beeson
44	Grub Gulf	55.7833	159.9306	1	Beeson
45	Ramsey Bay W.	55.8250	159.8333	1	Beeson
46	Ramsey Bay E.	55.8417	159.7500	1	Beeson

Table 2 (cont.)

47	Chankliut I. -1	56.1467	158.1328	2	Lowry
48	Chankliut I. -2	56.1414	158.1578	2	Lowry
49	Chignik Bay	56.4175	158.2750	2	Lowry
50	Cape Kumliun	56.4717	157.9567	2	Lowry
51	Unavikshak I. Reefs	56.4544	157.7250	2	Lowry
52	Unavikshak I. N.E.	56.4994	157.7025	2	Lowry
53	Aghiyuk I. N.E.	56.2128	156.7783	2	Lowry
54	Anowik I. -2	56.0708	156.6422	2	Lowry
55	Anowik I. -1	56.0825	156.6731	2	Lowry
56	Chirikof N. House	55.8047	155.7500	2	Lowry
57	Chirikof S. House	55.7997	155.7292	2	Lowry
58	Chirikof S.E.	55.7931	155.5536	2	Lowry
59	Chirikof E.	55.8144	155.5544	2	Lowry
60	Chirikof E. Nagai	55.8275	155.7478	2	Lowry
61	Kujulik Bay -1	56.5378	157.8044	2	Lowry
62	Unavikshak I. Reef N.W.	56.5569	157.5483	2	Lowry
63	Sutwik I. Reef N.	56.5944	157.3283	2	Lowry
64	Sutwik I.	56.5914	157.0872	2	Lowry
65	Kumlik I. Rock E.	56.6506	157.3181	2	Lowry
66	Kujulik Bay -3	56.5775	157.9503	2	Lowry
67	Kujulik Bay -2	56.5872	157.9089	2	Lowry
68	Eagle I.	56.7586	157.3472	2	Lowry
69	Amber Bay	56.8283	157.4164	2	Lowry
70	no name	56.7500	157.0119	2	Lowry
71	Yantari Bay I. S.E.	56.7981	157.0161	2	Lowry
72	Hydra I.	56.7433	157.0072	2	Lowry
73	Toee Reef	56.7619	156.8611	2	Lowry
74	Ugaiushak I.	56.8000	156.8475	2	Lowry
75	Aiugnak Columns -1	56.8789	156.5733	2	Lowry
76	Aiugnak Columns -2	56.8867	156.5706	2	Lowry
77	Agripina Bay	57.1067	156.4533	2	Lowry
78	Wide Bay S.	57.3336	156.2781	2	Lowry
79	Wide Bay N. -2	57.4553	156.1811	2	Lowry
80	Wide Bay N. -1	57.4611	156.1997	2	Lowry
81	Portage Bay	57.5367	156.0300	2	Lowry
82	Jute Bay	57.5528	155.8375	2	Lowry
83	Cape Aklek	57.6744	155.5783	2	Lowry
84	Puale Bay Rocks	57.6933	155.4164	2	Lowry
85	Alinchak Bay	57.7681	155.2778	2	Lowry
86	Alinchak Bay N.	57.8536	155.1581	2	Lowry
87	Kashvik Bay -1	57.9511	155.0569	2	Lowry
88	Katmai Bay E	58.0075	154.7619	2	Lowry
89	Takli I.	58.0481	154.5453	2	Lowry
90	Kinak Bay -2	58.1536	154.4406	2	Lowry
91	Kinak Bay -3	58.0794	154.4125	2	Lowry
92	Kinak Bay -1	58.1400	154.4339	2	Lowry
93	Missak Bay	58.1228	154.2778	2	Lowry
94	Kuliak Bay	58.1933	154.1586	2	Lowry
95	Kukak Bay	58.3144	154.2103	2	Lowry
96	Kukak Bay S.	58.2861	154.1044	2	Lowry
97	Cape Nushak	58.4189	153.9794	2	Lowry

Table 2 (con't.)

98	Hallo Bay	58.4725	154.0142	2	Lowry
99	Shakun Islets -2	58.5783	153.7072	2	Lowry
100	Shakun Islets -1	58.5692	153.6639	2	Lowry
101	Cape Douglas Rock S.	58.7361	153.3500	2	Lowry
102	Cape Douglas Reef S.	58.7606	153.2883	2	Lowry
103	Mt. Myrtle I.	57.2161	154.5906	3	Wynne
104	Olga Bay E.	57.1189	154.1428	3	Wynne
105	Olga Bay W.	57.0536	154.4389	3	Wynne
106	Sequoia River	56.9483	154.3578	3	Wynne
107	Fox I. Ledges	56.9839	154.0486	3	Wynne
108	Sulua Bay	56.9561	153.9136	3	Wynne
109	Alitak Reef	56.9147	154.0547	3	Wynne
110	Aiaktalik I.	56.7103	154.1083	3	Wynne
111	Sundstrom I. N.	56.6847	154.1319	3	Wynne
112	Tugidak N.	56.6044	154.4786	3	Wynne
113	Tugidak N.E.	56.5722	154.3831	3	Wynne
114	Tugidak Lgn. (Inside)	56.5458	154.4731	3	Wynne
115	Tugidak S.W.	56.4547	154.7783	3	Wynne
116	Tugidak Bar S.E.	56.5228	154.4172	3	Wynne
117	Sitkinak Lgn. N.	56.5578	154.0336	3	Wynne
118	Sitkinak Lgn. S.	56.5578	154.0336	3	Wynne
119	Sitkinak I. S.E.	56.5022	153.9714	3	Wynne
120	Sundstrom I. Ledge N.E.	56.6803	154.1061	3	Wynne
121	Aiaktalik Ledge S.E.	56.6761	153.9900	3	Wynne
122	Geese I. N.	56.7203	153.9258	3	Wynne
123	Geese I. S.	56.7203	153.9111	3	Wynne
124	Geese I. (Mid)	56.7222	153.8856	3	Wynne
125	Kaguyak (Inner)	56.8256	153.7919	3	Wynne
126	Kaguyak (Outer)	56.8303	153.7447	3	Wynne
127	Black Point	57.0072	153.3603	3	Wynne
128	Rolling Bay	57.0450	153.3736	3	Wynne
129	Kiliuda Bay (Upper)	57.3192	153.1628	3	Wynne
130	Barnabas Rocks	57.1856	152.9219	3	Wynne
131	Shearwater Bay	57.2947	152.8911	3	Wynne
132	Gull Point Lgn.	57.3369	152.6478	3	Wynne
133	Ugak I.	57.3756	152.2572	3	Wynne
134	Pasagshak W.	57.4344	152.5756	3	Wynne
135	Ugak Bay (Upper)	57.4775	152.8769	3	Wynne
136	Kalsin Bay	57.6447	152.3614	3	Wynne
137	Broad Point	57.6714	152.3944	3	Wynne
138	Cliff Point	57.7114	152.4328	3	Wynne
139	Womans Bay	57.7383	152.4328	3	Wynne
140	Long I.	57.7894	152.2200	3	Wynne
141 (& 103)	1-Mt. Myrtle I.	57.2153	154.5833	3	Olesiuk
142	2-Middle Cape 2	57.3411	154.7875	3	Olesiuk
143	3-Middle Cape 1	57.3550	154.8169	3	Olesiuk
144	4-Ugak Bay S Arm	57.3675	153.7792	3	Olesiuk
145	5-Zachar Bay	57.5425	153.7075	3	Olesiuk
146	7-E of Rocky Pt.	57.6558	154.0694	3	Olesiuk
147	6-Spiridon Bay	57.6531	153.6550	3	Olesiuk
148	8-Mink Pt.	57.7311	153.5494	3	Olesiuk

Table 2 (con't.)

149	10-Uganik I.	57.8039	153.2875	3	Olesiuk
150	11-Uganik E Passage	57.8361	153.0764	3	Olesiuk
151	9-Kizhuyak Bay S	57.7650	152.8672	3	Olesiuk
152	18-Malka Bay	58.1925	153.0017	3	Olesiuk
153	22-Foul Bay W	58.3575	152.8675	3	Olesiuk
154	23-Foul Bay E	58.3617	152.7889	3	Olesiuk
155	27-Peronosa Bay W 2	58.4239	152.4600	3	Olesiuk
156	26-Peronosa Bay W 1	58.4231	152.4672	3	Olesiuk
157	28Peronosa Bay W 3	58.4300	152.4617	3	Olesiuk
158	33-Andreon Bay E 1	58.5078	152.3922	3	Olesiuk
159	34-Andreon Bay E 2	58.5106	152.3900	3	Olesiuk
160	35-Andreon Bay W	58.5136	152.4206	3	Olesiuk
161	44-Big Bay	58.5769	152.6253	3	Olesiuk
162	40-Shuyak I. W 1	58.5475	152.3642	3	Olesiuk
163	45-Latax R.	58.6917	152.4836	3	Olesiuk
164	42-Shuyak I. W 2	58.5517	152.3561	3	Olesiuk
165	43-Shuyak I. W 3	58.5531	152.3444	3	Olesiuk
166	37-E of Tetrekof Pt. 1	58.5242	152.3508	3	Olesiuk
167	38-E of Tertrekof Pt. 2	58.5286	152.3244	3	Olesiuk
168	41-WNW of Sea Otter I.	58.5500	152.2769	3	Olesiuk
169	36-W of Sea Otter I.	58.5175	152.2856	3	Olesiuk
170	31-N of Posliedni Pt. 2	58.4481	152.3267	3	Olesiuk
171	29-N of Posliedni Pt. 1	58.4367	152.3022	3	Olesiuk
172	25-Seal I.	58.4050	152.2539	3	Olesiuk
173	24-Tolstoi Pt.	58.3853	152.1578	3	Olesiuk
174	21-Tonki Bay	58.3244	152.0675	3	Olesiuk
175	20-Marmot I. N	58.2564	151.8575	3	Olesiuk
176	19-Marmot I. E	58.2108	151.7958	3	Olesiuk
177	17-Duck Bay	58.0569	152.4258	3	Olesiuk
178	16-Skipwith Reefs 4	58.0364	152.6625	3	Olesiuk
179	15-Skipwith Reefs 3	58.0361	152.6889	3	Olesiuk
180	14-Skipwith Reefs 2	58.0292	152.6839	3	Olesiuk
181	13-Skipwith Reefs 1	58.0256	152.6789	3	Olesiuk
182	12-The Triplets	57.9906	152.4656	3	Olesiuk
183	Shaw I. N.E.	59.0117	153.3703	4	Mahoney
184	Shaw I. N.	59.0092	153.3728	4	Mahoney
185	Shaw I S.W.	58.9978	153.3778	4	Mahoney
186	Shaw I W.	59.0075	153.3992	4	Mahoney
187	Shaw I. N.W.	59.0114	153.3900	4	Mahoney
188	Douglas R. Reef N.E.	59.1039	153.6947	4	Mahoney
189	Douglas R. Reef N.	59.1081	153.8431	4	Mahoney
190	E of Akumwarik Bay	59.1086	154.1325	4	Mahoney
191	Mc Neil Head	59.1308	154.1178	4	Mahoney
192	Nordyke I.	59.1500	154.0711	4	Mahoney
193	Juma Reef S.	59.1706	154.0711	4	Mahoney
194	Juma Reef E.	59.1906	154.0769	4	Mahoney
195	Juma Reef W.	59.1936	154.0806	4	Mahoney
196	Juma Reef N.	59.1944	154.0683	4	Mahoney
197	E of Amakdedori	59.2739	153.9994	4	Mahoney
198	Laney Reef -2	59.2925	153.8844	4	Mahoney
199	Laney Reef -1	59.2972	153.8644	4	Mahoney

Table 2 (cont.)

200	Kirschner Lake	59.4147	153.8825	4	Mahoney
201	Augustine N.W. -1	59.3972	153.5658	4	Mahoney
202	Augustine N.W. -2	59.3675	153.5842	4	Mahoney
203	Augustine W.	59.3644	153.5869	4	Mahoney
204	Augustine S.S.W.	59.3167	153.4939	4	Mahoney
205	Augustine W. -1	59.3178	153.4686	4	Mahoney
206	Augustine S.W.	59.3208	153.4492	4	Mahoney
207	Augustine S.	59.3244	153.3947	4	Mahoney
208	Augustine S.S.E.	59.3264	153.3942	4	Mahoney
209	Augustine N.E.	59.4175	153.3961	4	Mahoney
210	Augustine (Burr Point)	59.4183	153.4067	4	Mahoney
211	Augustine E.N.E.	59.4192	153.3967	4	Mahoney
212	Augustine N-2	59.4103	153.4772	4	Mahoney
213	Augustine N.N.W.	59.4050	153.4825	4	Mahoney
214	Augustine N.	59.3989	153.5117	4	Mahoney
215	Turtle Reef	59.6033	153.5411	4	Mahoney
216	Black Reef	59.6247	153.5264	4	Mahoney
217	Vert I.	59.6275	153.4536	4	Mahoney
218	W of Scott I.	59.6411	153.4522	4	Mahoney
219	S of Vert I.	59.6261	153.4422	4	Mahoney
220	W of Iniskin I.	59.6244	153.4311	4	Mahoney
221	E of Iniskin I.	59.6258	153.4064	4	Mahoney
222	W. of Pomeroy I.	59.6178	153.3781	4	Mahoney
223	Big Rock	59.6136	153.3383	4	Mahoney
224	Little Jack Slough	60.5233	152.2497	4	Mahoney
225	Big River	60.6414	152.0222	4	Mahoney
226	N of Big River	60.6569	151.9847	4	Mahoney
227	Bradley R.	59.2022	151.1189	5	Payne
228	Yukon I.	59.5417	151.4567	5	Payne
229	Kamechak I.	59.7017	151.1333	5	Payne
230	Tonsini Bay	59.3208	150.8594	5	Payne
231	Home Cove-Nuka Passage	59.3833	150.7283	5	Payne
232	Tonsi-Long I.	59.4214	150.6786	5	Payne
233	Quartz Bay	59.4978	150.5000	5	Payne
234	N. Arm Ledge	59.5544	150.5381	5	Payne
235	James Lagoon	59.5736	150.3997	5	Payne
236	McCarty Glacier	59.7192	150.2194	5	Payne
237	Northwest	59.7958	150.0061	5	Payne
238	Pedersen Glacier	59.8683	149.7217	5	Payne
239	Hive I.	59.8811	149.3606	5	Payne
240	Bear Glacier	59.9322	149.5042	5	Payne
241	Aialik Glacier	59.9517	149.7331	5	Payne
242	Chickaloon	60.9164	150.0919	5	Payne

Table 3. The number of seals counted at each site for Area 1, south side of the Alaska Peninsula from Cold Bay to the Kupreanof Peninsula, including the Shumigan Islands.

Location	Latitude	Longitude	MAX	MEAN	8/25/96	8/26/96	8/27/96	8/28/96	8/29/96	8/30/96	8/31/96	9/1/96
Bird I.	54.6667	163.3000	75	36	15	17	75				35	
Bird I. N. W.	54.8214	159.7994	19	19						19		
Buyan Is.	54.9000	162.1167	72	31		9	72	12				
Cape Lazaref	54.6000	163.5833	60	31	18	27	60				17	
Cold Bay	55.2667	162.6333	109	65			57	64	63	64	30	109
Dolgoi I. N.	55.1500	161.7083	13	12				12	13	9		13
Dolgoi I. S.	55.0906	161.8231	12	7				11	12	4		2
Doreno Bay	55.6372	160.2694	23	12					10	4		23
Grub Gulf	55.7833	159.9306	12	8					12	4		
Guillemot I.	55.5500	160.3667	12	8					12	2		9
Iliasik (Outer)	55.0167	161.8667	42	23		18			23	7		42
Kennoys I.	55.1564	161.1061	82	56	37	61				82		42
Koniuji I.	55.0478	159.6311	20	12					20	9		7
Let I.	54.8417	162.4500	2	2			2					
Morahovoi Bay	55.1094	163.1464	87	54			79		15		87	35
N.E. of Hunt I.	54.7947	162.1797	3	2			1	2				3
Nagai I.	55.2397	159.9406	11	7				7	7	11		4
Nagai I. N.E.	55.2214	159.8831	25	16						6		25
Orzinski Bay	55.7000	160.0533	13	11					13			9
Patton I.	54.9011	162.1306	69	50			23	69				57
Paulof Bay	55.4833	161.6167	61	60					58	61		60
Paulof Bay N.	55.5478	161.5892	54	18				54	5	5		7
Paulof Bay S.	55.4000	161.6167	49	22				49	16	15		8
Popov I.	55.2844	160.4278	5	4		5		4	4	4		
Popov I. S.	55.2586	160.3786	6	3				1	1	4		6
Ramsey Bay E.	55.8417	159.7500	63	49						34		63
Ramsey Bay W.	55.8250	159.8333	14	11					8	14		10
S of Deer I.	54.8250	162.3500	29	19	21	27	8	29				10
S. of Cold Bay	55.2556	162.6889	10	10						10		
Sanak I.	54.5000	162.8667	333	279	269	216	333				296	
Sandman I.	54.7917	162.1750	90	61	45	90	82				28	
Sankin I.	54.8000	163.2667	30	20	30	18	12				20	
Sarana I.	54.9667	161.9167	18	9		18		9	8	3		9
Seal Cape	55.3522	161.2222	47	23				47	16	7		21
Simonof I. N.	54.9000	159.3333	79	33				18	16	79		17
Simonof I. S.	54.8667	159.2583	46	38				39		46		29
Sozavarika I.	54.8583	162.5167	68	45	39	68		32				42
Sushilnoi I.	54.8667	161.8583	15	10		15		5				
Turner I. W.	55.0469	159.8589	24	23						22		24
Ukolnoi I. N.	55.2608	161.5542	64	30				64	19	25		12

Table 3 (cont.)

Ukolnoi I. S.	55.2281	161.5378	11	9				11	11			6
Unaga I. N.	55.3250	160.6500	135	69	99	135		45	43	57		33
Unaga I. S.	55.1667	160.4833	84	22		4		84	6	6		10
Volcano Bay	55.1819	162.0011	27	20				23	13	27		16
Wosnesenski I. E.	55.2239	161.3472	6	3				6	2			2
Wosnesenski I. W.	55.2256	161.4536	1	1					1			
		totals	2130	1348	573	728	804	697	427	640	513	765

MAX	MEAN
2130	1348

95 % Confidence Interval	
1213 =LOW	1484 =HIGH

CV	COUNT	SD
5.06	156	68.29

Table 4. The number of seals counted at each site for Area 2, south side of the Alaska Peninsula from Chignik Bay to Cape Douglas, including the Semidi and Chirikof Islands.

Location	Latitude	Longitude	MAX	MEAN	8/25/96	8/26/96	8/27/96	8/27/96	8/28/96	8/28/96	8/29/96	8/30/96
Aghiyuk I. N.E.	56.2128	156.7783	23	10				23	0	17	0	
Agripina Bay	57.1067	156.4533	21	12	7		0	21	0		21	21
Aiugnak Columns -1	56.8789	156.5733	33	16	0		9	4	28		33	22
Aiugnak Columns -2	56.8867	156.5706	143	107	64		108	71	120		143	137
Alinchak Bay	57.7681	155.2778	139	88			139		26		90	99
Alinchak Bay N.	57.8536	155.1581	61	33			24		0		61	46
Amber Bay	56.8283	157.4164	40	20	0			1	40			37
Anowik I. -1	56.0825	156.6731	60	43				32	51	31	60	
Anowik I. -2	56.0708	156.6422	3	2				3	1	2	3	
Cape Aklek	57.6744	155.5783	8	4	0		8		6		1	6
Cape Douglas Reef S.	58.7606	153.2883	235	173		149	159				149	235
Cape Douglas Rock S.	58.7361	153.3500	11	9			7				11	9
Cape Kumliun	56.4717	157.9567	36	25	27			18		36		17
Cape Nushak	58.4189	153.9794	85	58			26				63	85
Chankliut I. -1	56.1467	158.1328	105	79	105			90		94		29
Chankliut I. -2	56.1414	158.1578	84	52	35			44		44		84
Chignik Bay	56.4175	158.2750	89	84	74			89		89		86
Chirikof E. Nagai	55.8275	155.7478	50	29				17	33	16	50	
Chirikof E.	55.8144	155.5544	58	44				58	36	55	29	
Chirikof N. House	55.8047	155.7500	68	60				68	60	46	66	
Chirikof S. House	55.7997	155.7292	4	3				2	4	4	2	
Chirikof S.E.	55.7931	155.5536	64	40				60	14	24	64	
Eagle I.	56.7586	157.3472	47	25	22			18	13			47
Hallo Bay	58.4725	154.0142	249	144		249	61				160	108
Hydra I.	56.7433	157.0072	53	34	14			22	46			53
no name	56.7500	157.0119	14	14	14							
Jute Bay	57.5528	155.8375	11	2	0		0		0		0	11
Kashvik Bay -1	57.9511	155.0569	47	23		0	47		2		41	28
Katmai Bay E	58.0075	154.7619	35	11		35	3		0		1	17
Kinak Bay -1	58.1400	154.4339	30	14		27	30				1	0
Kinak Bay -2	58.1536	154.4406	12	5		12	7				0	0
Kinak Bay -3	58.0794	154.4125	4	3		3	4				3	0
Kujulik Bay -1	56.5378	157.8044	11	11								11
Kujulik Bay -2	56.5872	157.9089	36	36								36
Kujulik Bay -3	56.5775	157.9503	7	7								7
Kukak Bay	58.3144	154.2103	44	30		20	44				31	24
Kukak Bay S.	58.2861	154.1044	62	15		62	0				0	0
Kuliak Bay	58.1933	154.1586	40	30		40	26				30	27

Table 4 (cont.)

Kumlik I. Rock E.	56.6506	157.3181	24	18				18	24	19		11
Missak Bay	58.1228	154.2778	16	10		8	5				16	9
Portage Bay	57.5367	156.0300	54	27	10		29		17		26	54
Puale Bay Rocks	57.6933	155.4164	25	15	0		20		14		25	18
Shakun Islets -1	58.5692	153.6639	19	8		2	0				19	9
Shakun Islets -2	58.5783	153.7072	88	66		88	61				58	58
Sutwik I.	56.5914	157.0872	11	10				8	9		10	11
Sutwik I. Reef N.	56.5944	157.3283	2	2								2
Takli I.	58.0481	154.5453	19	5		19	0				0	0
Tose Reef	56.7619	156.8611	17	8	0		3	10	6		17	14
Ugaiushak I.	56.8000	156.8475	133	99	79		48	116	102		133	116
Unavikshak I. N.E.	56.4994	157.7025	28	26				27		22		28
Unavikshak I. Reef N.W.	56.5569	157.5483	52	27				28		52		0
Unavikshak I. Reefs	56.4544	157.7250	8	4				4		0		8
Wide Bay N. -1	57.4611	156.1997	60	23	0		0	0	38		39	60
Wide Bay N. -2	57.4553	156.1811	18	6	0		0	2	1		15	18
Wide Bay S.	57.3336	156.2781	152	103	54		110	81	97		152	123
Yantari Bay I. S.E.	56.7981	157.0161	9	4	0			0	9			8
		totals	2848	1852	504	712	975	933	794	548	1616	1825

MAX	MEAN
2848	1852

95 % Confidence Interval	
1684 =LOW	2021 =HIGH

CV	COUNT	SD
4.60	226	85.23

** = haulout awash, or tide much higher than normal
= disturbance suspected
+ + = no disturbance, but seals in water adjacent to haulout
-- = this value not used to calculate mean (observer noted a reason, other than those above, why count is not typical or representative)
blank indicates site not surveyed

Table 5. The number of seals counted at each site for Area 3, Kodiak Archipelago including Tugidak Island.

Location	Latitude	Longitude	MAX	MEAN	8/25/96	8/26/96	8/27/96	8/28/96	8/29/96	8/30/96	8/31/96	9/1/96	9/2/96	9/3/96
Aiaktalik I.	56.7103	154.1083	70	62				58	68	70	66	45	64	
Aiaktalik Ledge S.E.	56.6761	153.9900	29	19				0	19	24	29	25	18	
Alitak Reef	56.9147	154.0547	26	22								24	15	26
Barnabas Rocks	57.1856	152.9219	49	24				28	16	49	35	13	0 –	5
Black Point	57.0072	153.3603	117	62				38	61	17	117	26	95	81
Broad Point	57.6714	152.3944	2	0				0	0	2	0	0		0
Cliff Point	57.7114	152.4328	15	2				2	0	15	0	0	0	0
Fox I. Ledges	56.9839	154.0486	44	34									24	44
Geese I. (Mid)	56.7222	153.8856	23	13				4	9	18	10	23	14	
Geese I. N.	56.7203	153.9258	168	140				88	113	168	161	160	150	
Geese I. S.	56.7203	153.9111	5	3				0 **	4	5	5	0	0	
Gull Point Lgn.	57.3369	152.6478	81	60					46	61	81	73	0 ++	39
Kaguyak (Inner)	56.8256	153.7919	15	8				2	0	13	13	0	10	15
Kaguyak (Outer)	56.8303	153.7447	5	1				0	0	0	0	0	5	3
Kalsin Bay	57.6447	152.3614	127	104				104	119	73	111	93	99	127
Kiliuda Bay (Upper)	57.3192	153.1628	23	11				0 –	0 ++	0	0	15	19	23
Long I.	57.7894	152.2200	52	35				52	41	42	29	23	28	29
Mt. Myrtle I.[1]	57.2161	154.5906	277	194						139	206	189	181	192
Olga Bay E.	57.1189	154.1428	18	16				14	0 ++	0 **				18
Olga Bay W.	57.0536	154.4389	111	86				87	82	111	86	57	79	101
Pasagshak W.	57.4344	152.5756	113	69				58	93	77	78	29	34	113
Rolling Bay	57.0450	153.3736	58	46				17	53	47	48	58	50	50
Sukhoi River	56.9483	154.3578	140	87				60	107	121	28	36	119	140
Shearwater Bay	57.2947	152.8911	87	74				63	73	87	84	54	76	82
Sitkinak I. S.E.	56.5022	153.9714	182	151				171	142	143	182	157	113	
Sitkinak Lgn. N.	56.5578	154.0336	82	64				61	82	28	59	80	71	
Sitkinak Lgn. S.	56.5578	154.0336	84	54				72	22	40	21	82	84	
Sulua Bay	56.9561	153.9136	100	71				0 **	0 ++		42	60	81	100
Sundstrom I. Ledge N.	56.6803	154.1061	16	10				0 **	16	7	9	8	8	
Sundstrom I. N.	56.6847	154.1319	2	1				0	2	2	0	0	0	
Tugidak Bar S.E.	56.5228	154.4172	199	157				154	173	186	148	199	81	
Tugidak Lgn. (Inside)	56.5458	154.4731	122	99				102	90	101	119	60	122	
Tugidak N.	56.6044	154.4786	187	76				0	0	126	187	0	140	
Tugidak N.E.	56.5722	154.3831	414	319				414	281	301	203	398	318	
Tugidak S.W.	56.4547	154.7783	959	694				562	307	812	829	0 ##	959	
Ugak Bay (Upper)	57.4775	152.8769	36	14				0	0	14	20	36	29	0
Ugak I.	57.3756	152.2572	287	217				276	238	229	248	287	239	0 –
Womans Bay	57.7383	152.4328	46	24				0 ##	1	0 ++	19	38	15	46
1-Mt. Myrtle I.[1]	57.2153	154.5833				277					192		173	
2-Middle Cape 2	57.3411	154.7875	45	38							31		45	
3-Middle Cape 1	57.3550	154.8169	13	8		0					2		13	
4-Uyak Bay S Arm	57.3675	153.7792	108	77		59			72		108		70	
5-Zachar Bay	57.5425	153.7075	31	31			31		0		0			
6-Spiridon Bay	57.6531	153.6550	87	63			42		50		87		73	
7-E of Rocky Pt.	57.6558	154.0694	21	17		16			21		20		11	

Table 5 (con't.)

8-Mink Pt.	57.7311	153.5494	84	75			57		84		82		77	
9-Kizhuyak Bay S	57.7650	152.8672	14	8			14			2				
10-Uganik I.	57.8039	153.2875	75	52			74		35		75		25	
11-Uganik E Passage	57.8361	153.0764	80	58					29	80	62		62	
12-The Triplets	57.9906	152.4656	20	14				16	20	12	11		13	
13-Skipwith Reefs 1	58.0256	152.6789	299	167		86		51		155	134	299		277
14-Skipwith Reefs 2	58.0292	152.6839	23	14		5		15						23
15-Skipwith Reefs 3	58.0361	152.6889	22	12		22								2
16-Skipwith Reefs 4	58.0364	152.6625	5	5		5								
17-Duck Bay	58.0569	152.4258	78	41		78		27	38	27	23	43		54
18-Malka Bay	58.1925	153.0017	27	17	25			0	0	2		27		13
19-Marmot I. E	58.2108	151.7958	6	6		6		6		4		6		6
20-Marmot I. N	58.2564	151.8575	26	16		15		13		12		26		16
21-Tonki Bay	58.3244	152.0675	38	23		14		18		38		19		25
22-Foul Bay W	58.3575	152.8675	24	12	14			7		8		8		24
23-Foul Bay E	58.3617	152.7889	28	17	17			0	17	5		0		28
24-Tolstoi Pt.	58.3853	152.1578	10	7		4		10		6		6	0	
25-Seal I.	58.4050	152.2539	140	102	51	93		95		96		134		140
26-Peronosa Bay W 1	58.4231	152.4672	70	60	49									70
27-Peronosa Bay W 2	58.4239	152.4600	94	74	60			82		94		60		72
28Peronosa Bay W 3	58.4300	152.4617	59	33				7				59		
29-N of Posliedni Pt. 1	58.4367	152.3022	9	6	4	3		8		9		0		0
31-N of Posliedni Pt. 2	58.4481	152.3267	53	36	53	47		0		29		28		22
33-Andreon Bay E 1	58.5078	152.3922	35	35				35						
34-Andreon Bay E 2	58.5106	152.3900	34	34						34				
35-Andreon Bay W	58.5136	152.4206	23	23	23									23
36-W of Sea Otter I.	58.5175	152.2856	29	22	21			21		16		22		29
37-E of Tetrekof Pt. 1	58.5242	152.3508	71	49	42			50		13		71		70
38-E of Tertrekof Pt. 2	58.5286	152.3244	4	3				3		1				4
40-Shuyak I. W 1	58.5475	152.3642	4	3						4		1		
41-WNW of Sea Otter	58.5500	152.2769	21	18	15			21						
42-Shuyak I. W 2	58.5517	152.3561	27	15	27			15		18		0		0
43-Shuyak I. W 3	58.5531	152.3444	22	10				2		5		22		
44-Big Bay	58.5769	152.6253	25	22								19		25
45-Latax R.	58.6917	152.4836	12	8	6			8		4		12		12
		totals =	6267	4450	407	730	218	2997	2624	3802	4100	3210	3902	2170

MAX	MEAN
6267	4437

95 % Confidence Interval			
4129	=LOW	4745	=HIGH

CV	COUNT	SD
3.53	382	156.429

1 = This haulout was surveyed by both Wynne and Olesiuk. N, mean, max, s.d. and other statistical values are combined and calculated only once.
** = haulout awash, or tide much higher than normal
= disturbance suspected
++ = no disturbance, but seals in water adjacent to haulout
-- = this value not used to calculate mean (observer noted a reason, other than those above, why count is not typical or representative)
blank indicates site not surveyed

Table 6. The number of seals counted at each site for Area 4, north side of Cook Inlet from Anchorage to Cape Douglas.

Location	Latitude	Longitude	MAX	MEAN	8/25/96	8/26/96	8/27/96	8/28/96	8/29/96	8/30/96	8/31/96	9/1/96	9/2/96
Shaw I S.W.	58.9978	153.3778	31	22				3	31	24	27	19	29
Shaw I W.	59.0075	153.3992	188	71				96	2	69	65	4	188
Shaw I. N.	59.0092	153.3728	10	6								1	10
Shaw I. N.W.	59.0114	153.3900	190	156				133	179	155	184	190	94
Shaw I. N.E.	59.0117	153.3703	81	55				81	47	35	31	62	73
Douglas R. Reef N.E.	59.1039	153.6947	236	160				236	175	135	116	155	142
Douglas R. Reef N.	59.1081	153.8431	178	104					34	127	125	178	55
E of Akumwarik Bay	59.1086	154.1325	117	94					117	116		64	79
Mc Neil Head	59.1308	154.1178	139	69			139			49	34	55	
Nordyke I.	59.1500	154.0711	23	23			23						
Juma Reef S.	59.1706	154.0711	19	19			19						
Juma Reef E.	59.1906	154.0769	3	3								3	
Juma Reef W.	59.1936	154.0806	87	63				59	65	57	36	87	76
Juma Reef N.	59.1944	154.0683	73	73			73						
E of Amakdedori	59.2739	153.9994	90	63				48	65	90	58	39	77
Laney Reef -2	59.2925	153.8844	235	159			37	152	235	168	201	159	164
Laney Reef -1	59.2972	153.8644	98	59			98	20					
Augustine S.S.W.	59.3167	153.4939	9	9			9						
Augustine W. -1	59.3178	153.4686	2	2.						2			
Augustine S.W.	59.3208	153.4492	40	35						30			40
Augustine S.	59.3244	153.3947	242	176			194			242	210		56
Augustine S.S.E.	59.3264	153.3942	190	190		190							
Augustine W.	59.3644	153.5869	37	29							21		37
Augustine N.W. -2	59.3675	153.5842	2	2									2
Augustine N.W. -1	59.3972	153.5658	9	8			9						6
Augustine N.	59.3989	153.5117	17	16			14						17
Augustine N.N.W.	59.4050	153.4825	2	2					1	2			2
Augustine N-2	59.4103	153.4772	1	1					1			1	
Kirschner Lake	59.4147	153.8825	4	4			4						
Augustine N.E.	59.4175	153.3961	80	42					30		14	44	80
Augustine (Burr Point)	59.4183	153.4067	33	33				33					
Augustine E.N.E.	59.4192	153.3967	1	1			1						
Turtle Reef	59.6033	153.5411	33	30		28				33	30		28
Big Rock	59.6136	153.3383	91	55		24		65	52		18	81	91
W. of Pomeroy I.	59.6178	153.3781	4	4						4			
W of Iniskin I.	59.6244	153.4311	61	33					5		36	61	30
Black Reef	59.6247	153.5264	10	7						10	3		9
E of Iniskin I.	59.6258	153.4064	146	88		69		143	52	54	90	65	146
S of Vert I.	59.6261	153.4422	83	39		83		16	14		42	28	52
Vert I.	59.6275	153.4536	48	48						48			

Table 6 (cont.)

W of Scott I.	59.6411	153.4522	23	13				10			23		5
Little Jack Slough	60.5233	152.2497	26	16					5	28			
Big River	60.6414	152.0222	84	46			23		30	84			
N of Big River	60.6569	151.9847	266	118	76		77		41	64	222	83	266
			totals =	2244	76	394	720	1095	1181	1624	1586	1379	1854

MAX	MEAN
3342	2244

95 % Confidence Interval	
1779 =LOW	2709 =HIGH

CV	COUNT	SD
10.46	145	234.68

Table 7. The number of seals counted at each site for Area 5, Kenai Peninsula.

Location	Latitude	Longitude	MAX	MEAN	8/26/96	8/27/96	8/28/96	8/29/96	8/30/96	8/31/96	9/2/96
Aialik Glacier	59.9517	149.7331	85	50	85	11	45	76	63	67	3
Bear Glacier	59.9322	149.5042	8	5	8			5		2	
Bradley R.	59.2022	151.1189	400	313	352	300	400				200
Chickaloon	60.9164	150.0919	13	10				6			13
Hive I.	59.8811	149.3606	4	3	4	3					2
Home Cove-Nuka Passage	59.3833	150.7283	6	6						6	
James Lagoon	59.5736	150.3997	10	10				10			
Kamechak I.	59.7017	151.1333	53	49		53	45				
McCarty Glacier	59.7192	150.2194	160	118	141	122	160	130		76	81
N. Arm Ledge	59.5544	150.5381	39	21	14				11	39	19
Northwest	59.7958	150.0061	76	35	32	76	26	9	32	56	15
Pedersen Glacier	59.8683	149.7217	114	72	95	52	114	72	65	36	70
Quartz Bay	59.4978	150.5000	20	6	1				20	1	1
Tonsi-Long I.	59.4214	150.6786	12	8	11					1	12
Tonsini Bay	59.3208	150.8594	7	7					7		
Yukon I.	59.5417	151.4567	1	1		1					
		Totals =	1008	713	743	618	790	308	198	284	416

MAX	MEAN
1008	713

95 % Confidence Interval			
610	=LOW	817	=HIGH

CV	COUNT	SD
7.19	56	51.33

Table 8. The number of seals counted at each site for all areas, from the south side of the Alaska Peninsula to the Kenai Peninsula.

Location	Latitude	Longitude	MAX	MEAN	8/25	8/26	8/27	8/27	8/28	8/28	8/29	8/30	8/31	9/1	9/2	9/3
Bird I.	54.6667	163.3000	75	36	15	17	75						35			
Bird I. N. W.	54.8214	159.7994	19	19								19				
Buyan Is.	54.9000	162.1167	72	31		9	72		12							
Cape Lazaref	54.6000	163.5833	60	31	18	27	60						17			
Cold Bay	55.2667	162.6333	109	65			57		64		63	64	30	109		
Dolgoi I. N.	55.1500	161.7083	13	12					12		13	9		13		
Dolgoi I. S.	55.0906	161.8231	12	7					11		12	4		2		
Doreno Bay	55.6372	160.2694	23	12							10	4		23		
Grub Gulf	55.7833	159.9306	12	8							12	4				
Guillemot I.	55.5500	160.3667	12	8							12	2		9		
Iliasik (Outer)	55.0167	161.8667	42	23		18					23	7		42		
Kennoys I.	55.1564	161.1061	82	56	37	61						82		42		
Koniuji I.	55.0478	159.6311	20	12							20	9		7		
Let I.	54.8417	162.4500	2	2			2									
Morahovoi Bay	55.1094	163.1464	87	54			79				15		87	35		
N.E. of Hunt I.	54.7947	162.1797	3	2			1		2					3		
Nagai I.	55.2397	159.9406	11	7					7		7	11		4		
Nagai I. N.E.	55.2214	159.8831	25	16								6		25		
Orzinski Bay	55.7000	160.0533	13	11							13			9		
Patton I.	54.9011	162.1306	69	50			23		69					57		
Paulof Bay	55.4833	161.6167	61	60							58	61		60		
Paulof Bay N.	55.5478	161.5892	54	18					54		5	5		7		
Paulof Bay S.	55.4000	161.6167	49	22					49		16	15		8		
Popov I.	55.2844	160.4278	5	4		5			4		4	4				
Popov I. S.	55.2586	160.3786	6	3					1		1	4		6		
Ramsey Bay E.	55.8417	159.7500	63	49								34		63		
Ramsey Bay W.	55.8250	159.8333	14	11							8	14		10		
S of Deer I.	54.8250	162.3500	29	19	21	27	8		29					10		
S. of Cold Bay	55.2556	162.6889	10	10								10				
Sanak I.	54.5000	162.8667	333	279	269	216	333						296			
Sandman I.	54.7917	162.1750	90	61	45	90	82						28			
Sankin I.	54.8000	163.2667	30	20	30	18	12						20			
Sarana I.	54.9667	161.9167	18	9		18			9		8	3		9		
Seal Cape	55.3522	161.2222	47	23					47		16	7		21		
Simonof I. N.	54.9000	159.3333	79	33					18		16	79		17		
Simonof I. S.	54.8667	159.2583	46	38					39			46		29		
Sozavarika I.	54.8583	162.5167	68	45	39	68			32					42		
Sushilnoi I.	54.8667	161.8583	15	10		15			5							
Turner I. W.	55.0469	159.8589	24	23								22		24		
Ukolnoi I. N.	55.2608	161.5542	64	30					64		19	25		12		

Table 8 (cont.)

Ukolnoi I. S.	55.2281	161.5378	11	9					11		11			6		
Unaga I. N.	55.3250	160.6500	135	69	99	135			45		43	57		33		
Unaga I. S.	55.1667	160.4833	84	22		4			84		6	6		10		
Volcano Bay	55.1819	162.0011	27	20					23		13	27		16		
Wosnesenski I. E.	55.2239	161.3472	6	3					6		2			2		
Wosnesenski I. W.	55.2256	161.4536	1	1							1					
Aghiyuk I. N.E.	56.2128	156.7783	23	10				23	0	17	0					
Agripina Bay	57.1067	156.4533	21	12	7		0	21	0		21	21				
Aiugnak Columns -1	56.8789	156.5733	33	16	0		9	4	28		33	22				
Aiugnak Columns -2	56.8867	156.5706	143	107	64		108	71	120		143	137				
Alinchak Bay	57.7681	155.2778	139	88			139		26		90	99				
Alinchak Bay N.	57.8536	155.1581	61	33			24		0		61	46				
Amber Bay	56.8283	157.4164	40	20	0			1	40			37				
Anowik I. -1	56.0825	156.6731	60	43				32	51	31	60					
Anowik I. -2	56.0708	156.6422	3	2				3	1	2	3					
Cape Aklek	57.6744	155.5783	8	4	0		8		6		1	6				
Cape Douglas Reef S.	58.7606	153.2883	235	173		149	159				149	235				
Cape Douglas Rock S.	58.7361	153.3500	11	9			7				11	9				
Cape Kumliun	56.4717	157.9567	36	25	27			18		36		17				
Cape Nushak	58.4189	153.9794	85	58			26				63	85				
Chankliut I. -1	56.1467	158.1328	105	79	105			90		94		29				
Chankliut I. -2	56.1414	158.1578	84	52	35			43.5		44		84				
Chignik Bay	56.4175	158.2750	89	84	74			89		89		86				
Chirikof E. Nagai	55.8275	155.7478	50	29				17	33	16	50					
Chirikof E.	55.8144	155.5544	58	44				58	36	55	29					
Chirikof N. House	55.8047	155.7500	68	60				68	59.5	46	65.5					
Chirikof S. House	55.7997	155.7292	4	3				2	4	4	2					
Chirikof S.E.	55.7931	155.5536	64	40				60	14	24	64					
Eagle I.	56.7586	157.3472	47	25	22			18	13			47				
Hallo Bay	58.4725	154.0142	249	144		249	61				160	108				
Hydra I.	56.7433	157.0072	53	34	14			22	46			53				
no name	56.7500	157.0119	14	14	14											
Jute Bay	57.5528	155.8375	11	2	0		0		0		0	11				
Kashvik Bay -1	57.9511	155.0569	47	23		0	47		2		41	28				
Katmai Bay E	58.0075	154.7619	35	11		35	3		0		1	17				
Kinak Bay -1	58.1400	154.4339	30	14		27	30				1	0				
Kinak Bay -2	58.1536	154.4406	12	5		12	7				0	0				
Kinak Bay -3	58.0794	154.4125	4	3		3	4				3	0				
Kujulik Bay -1	56.5378	157.8044	11	11								11				
Kujulik Bay -2	56.5872	157.9089	36	36								36				
Kujulik Bay -3	56.5775	157.9503	7	7								7				
Kukak Bay	58.3144	154.2103	44	30		20	44				31	24				
Kukak Bay S.	58.2861	154.1044	62	15		62	0				0	0				
Kuliak Bay	58.1933	154.1586	40	30		40	26				30	27				
Kumlik I. Rock E.	56.6506	157.3181	24	18				18	24	19		11				
Missak Bay	58.1228	154.2778	16	10		8	5				16	9				

Table 8 (cont.)

Portage Bay	57.5367	156.0300	54	27	10		29		17		26	54				
Puale Bay Rocks	57.6933	155.4164	25	15	0		20		14		25	18				
Shakun Islets -1	58.5692	153.6639	19	8		2	0				19	9				
Shakun Islets -2	58.5783	153.7072	88	66		88	61				58	58				
Sutwik I.	56.5914	157.0872	11	10				8	9		10	11				
Sutwik I. Reef N.	56.5944	157.3283	2	2								2				
Takli I.	58.0481	154.5453	19	5		19	0				0	0				
Toee Reef	56.7619	156.8611	17	8	0		3	10	6		17	14				
Ugaiushak I.	56.8000	156.8475	133	99	79		48	116	102		133	116				
Unavikshak I. N.E.	56.4994	157.7025	28	26				27		22		28				
Unavikshak I. Reef N.	56.5569	157.5483	52	27				28		52		0				
Unavikshak I. Reefs	56.4544	157.7250	8	4				4		0		8				
Wide Bay N. -1	57.4611	156.1997	60	23	0		0	0	38		39	60				
Wide Bay N. -2	57.4553	156.1811	18	6	0		0	2	1		15	18				
Wide Bay S.	57.3336	156.2781	152	103	54		110	81	97		152	123				
Yantari Bay I. S.E.	56.7981	157.0161	9	4	0			0	9			8				
Aiaktalik I.	56.7103	154.1083	70	62					58		68	70	66	45	64	
Aiaktalik Ledge S.E.	56.6761	153.9900	29	19					0		19	24	29	25	18	
Alitak Reef	56.9147	154.0547	26	22										24	15	26
Barnabas Rocks	57.1856	152.9219	49	24					28		16	49	35	13		5
Black Point	57.0072	153.3603	117	62					38		61	17	117	26	95	81
Broad Point	57.6714	152.3944	2	0					0		0	2	0	0		0
Cliff Point	57.7114	152.4328	15	2					2		0	15	0	0	0	0
Fox I. Ledges	56.9839	154.0486	44	34											24	44
Geese I. (Mid)	56.7222	153.8856	23	13					4		9	18	10	23	14	
Geese I. N.	56.7203	153.9258	168	140					88		113	168	161	160	150	
Geese I. S.	56.7203	153.9111	5	3							4	5	5	0	0	
Gull Point Lgn.	57.3369	152.6478	81	60							46	61	81	73		39
Kaguyak (Inner)	56.8256	153.7919	15	8					2		0	13	13	0	10	15
Kaguyak (Outer)	56.8303	153.7447	5	1					0		0	0	0	0	5	3
Kalsin Bay	57.6447	152.3614	127	104					104		119	73	111	93	99	127
Kiliuda Bay (Upper)	57.3192	153.1628	23	11								0	0	15	19	23
Long I.	57.7894	152.2200	52	35					52		41	42	29	23	28	29
Mt. Myrtle I.[1]	57.2161	154.5906	277	194								139	206	189	181	192
Olga Bay E.	57.1189	154.1428	18	16					14							18
Olga Bay W.	57.0536	154.4389	111	86					87		82	111	86	57	79	101
Pasagshak W.	57.4344	152.5756	113	69					58		93	77	78	29	34	113
Rolling Bay	57.0450	153.3736	58	46					17		53	47	48	58	50	50
Sequoia River	56.9483	154.3578	140	87					60		107	121	28	36	119	140
Shearwater Bay	57.2947	152.8911	87	74					63		73	87	84	54	76	82
Sitkinak I. S.E.	56.5022	153.9714	182	151					171		142	143	182	157	113	
Sitkinak Lgn. N.	56.5578	154.0336	82	64					61		82	28	59	80	71	
Sitkinak Lgn. S.	56.5578	154.0336	84	54					72		22	40	21	82	84	
Sulua Bay	56.9561	153.9136	100	71									42	60	81	100
Sundstrom I. Ledge N.	56.6803	154.1061	16	10							16	7	9	8	8	
Sundstrom I. N.	56.6847	154.1319	2	1					0		2	2	0	0	0	

Table 8 (cont.)

Tugidak Bar S.E.	56.5228	154.4172	199	157					154		173	186	148	199	81	
Tugidak Lgn. (Inside)	56.5458	154.4731	122	99					102		90	101	119	60	122	
Tugidak N.	56.6044	154.4786	187	76					0		0	126	187	0	140	
Tugidak N.E.	56.5722	154.3831	414	319					414		281	301	203	398	318	
Tugidak S.W.	56.4547	154.7783	959	694					562		307	812	829		959	
Ugak Bay (Upper)	57.4775	152.8769	36	14					0		0	14	20	36	29	0
Ugak I.	57.3756	152.2572	287	253					276		238	229	248	287	239	
Womans Bay	57.7383	152.4328	46	24							1		19	38	15	46
1-Mt. Myrtle I.[1]	57.2153	154.5833				277							192		173	
2-Middle Cape 2	57.3411	154.7875	45	38									31		45	
3-Middle Cape 1	57.3550	154.8169	13	5		0							2		13	
4-Ugak Bay S Arm	57.3675	153.7792	108	77		59					72		108		70	
5-Zachar Bay	57.5425	153.7075	31	8			31				0		0		0	
6-Spiridon Bay	57.6531	153.6550	87	63			42				50		87		73	
7-E of Rocky Pt.	57.6558	154.0694	21	17		16					21		20		11	
8-Mink Pt.	57.7311	153.5494	84	75			57				84		82		77	
9-Kizhuyak Bay S	57.7650	152.8672	14	8			14					2				
10-Uganik I.	57.8039	153.2875	75	52			74				35		75		25	
11-Uganik E Passage	57.8361	153.0764	80	58							29	80	62		62	
12-The Triplets	57.9906	152.4656	20	14					16		20	12	11		13	
13-Skipwith Reefs 1	58.0256	152.6789	299	167		86			51			155	134	299		277
14-Skipwith Reefs 2	58.0292	152.6839	23	14		5			15							23
15-Skipwith Reefs 3	58.0361	152.6889	22	12		22										2
16-Skipwith Reefs 4	58.0364	152.6625	5	5		5										
17-Duck Bay	58.0569	152.4258	78	41		78			27		38	27	23	43		54
18-Malka Bay	58.1925	153.0017	27	11	25				0		0	2		27		13
19-Marmot I. E	58.2108	151.7958	6	6		6			6			4		6		6
20-Marmot I. N	58.2564	151.8575	26	16		15			13			12		26		16
21-Tonki Bay	58.3244	152.0675	38	23		14			18			38		19		25
22-Foul Bay W	58.3575	152.8675	24	12	14				7			8		8		24
23-Foul Bay E	58.3617	152.7889	28	11	17				0		17	5		0		28
24-Tolstoi Pt.	58.3853	152.1578	10	5		4			10			6		6	0	
25-Seal I.	58.4050	152.2539	140	102	51	93			95			96		134		140
26-Peronosa Bay W 1	58.4231	152.4672	70	60	49											70
27-Peronosa Bay W 2	58.4239	152.4600	94	74	60				82			94		60		72
28Peronosa Bay W 3	58.4300	152.4617	59	33					7					59		
29-N of Posliedni Pt. 1	58.4367	152.3022	9	4	4	3			8			9		0		0
31-N of Posliedni Pt. 2	58.4481	152.3267	53	30	53	47			0			29		28		22
33-Andreon Bay E 1	58.5078	152.3922	35	35					35							
34-Andreon Bay E 2	58.5106	152.3900	34	34								34				
35-Andreon Bay W	58.5136	152.4206	23	23	23											23
36-W of Sea Otter I.	58.5175	152.2856	29	22	21				21			16		22		29
37-E of Tetrekof Pt. 1	58.5242	152.3508	71	49	42				50			13		71		70
38-E of Tertrekof Pt. 2	58.5286	152.3244	4	3					3			1				4
40-Shuyak I. W 1	58.5475	152.3642	4	3								4		1		
41-WNW of Sea Otter	58.5500	152.2769	21	18	15				21							

Table 8 (cont.)

42-Shuyak I. W 2	58.5517	152.3561	27	12	27				15			18		0		0
43-Shuyak I. W 3	58.5531	152.3444	22	10					2			5		22		
44-Big Bay	58.5769	152.6253	25	22										19		25
45-Latax R.	58.6917	152.4836	12	8	6				8			4		12		12
Shaw I S.W.	58.9978	153.3778	31	22					3		31	24	27	19	29	
Shaw I W.	59.0075	153.3992	188	71					96		2	69	65	4	188	
Shaw I. N.	59.0092	153.3728	10	6										1	10	
Shaw I. N.W.	59.0114	153.3900	190	156					133		179	155	184	190	94	
Shaw I. N.E.	59.0117	153.3703	81	55					81		47	35	31	62	73	
Douglas R. Reef N.E.	59.1039	153.6947	236	160					236		175	135	116	155	142	
Douglas R. Reef N.	59.1081	153.8431	178	104							34	127	125	178	55	
E of Akumwarik Bay	59.1086	154.1325	117	94							117	116		64	79	
Mc Neil Head	59.1308	154.1178	139	69			139					49	34	55		
Nordyke I.	59.1500	154.0711	23	23			23									
Juma Reef S.	59.1706	154.0711	19	19			19									
Juma Reef E.	59.1906	154.0769	3	3										3		
Juma Reef W.	59.1936	154.0806	87	63					59		65	57	36	87	76	
Juma Reef N.	59.1944	154.0683	73	73			73									
E of Amakdedori	59.2739	153.9994	90	63					48		65	90	58	39	77	
Laney Reef -2	59.2925	153.8844	235	159			37		152		235	168	201	159	164	
Laney Reef -1	59.2972	153.8644	98	59			98		20							
Augustine S.S.W.	59.3167	153.4939	9	9			9									
Augustine W. -1	59.3178	153.4686	2	2								2				
Augustine S.W.	59.3208	153.4492	40	35								30			40	
Augustine S.	59.3244	153.3947	242	176			194					242	210		56	
Augustine S.S.E.	59.3264	153.3942	190	190		190										
Augustine W.	59.3644	153.5869	37	29									21		37	
Augustine N.W. -2	59.3675	153.5842	2	2											2	
Augustine N.W. -1	59.3972	153.5658	9	8			9								6	
Augustine N.	59.3989	153.5117	17	16			14								17	
Augustine N.N.W.	59.4050	153.4825	2	2							1	2			2	
Augustine N-2	59.4103	153.4772	1	1							1			1		
Kirschner Lake	59.4147	153.8825	4	4			4									
Augustine N.E.	59.4175	153.3961	80	42							30		14	44	80	
Augustine (Burr Point)	59.4183	153.4067	33	33					33							
Augustine E.N.E.	59.4192	153.3967	1	1			1									
Turtle Reef	59.6033	153.5411	33	30		28						33	30		28	
Big Rock	59.6136	153.3383	91	55		24			65		52		18	81	91	
W. of Pomeroy I.	59.6178	153.3781	4	4								4				
W of Iniskin I.	59.6244	153.4311	61	33							5		36	61	30	
Black Reef	59.6247	153.5264	10	7								10	3		9	
E of Iniskin I.	59.6258	153.4064	146	88		69			143		52	54	90	65	146	
S of Vert I.	59.6261	153.4422	83	39		83			16		14		42	28	52	
Vert I.	59.6275	153.4536	48	48								48				
W of Scott I.	59.6411	153.4522	23	13					10				23		5	
Little Jack Slough	60.5233	152.2497	26	16							5	26				

Table 8 (cont.)

Big River	60.6414	152.0222	84	46			23				30	84				
N of Big River	60.6569	151.9847	266	118	76		77				41	64	222	83	266	
Aialik Glacier	59.9517	149.7331	85	50		85	11		45		76	63	67	3		
Bear Glacier	59.9322	149.5042	8	5		8					5		2			
Bradley R.	59.2022	151.1189	400	313		352	300		400					200		
Chickaloon	60.9164	150.0919	13	10							6			13		
Hive I.	59.8811	149.3606	4	3		4	3							2		
Home Cove-Nuka Pass	59.3833	150.7283	6	6									6			
James Lagoon	59.5736	150.3997	10	10							10					
Kamechak I.	59.7017	151.1333	53	49			53		45							
McCarty Glacier	59.7192	150.2194	160	118		141	122		160		130		76	81		
N. Arm Ledge	59.5544	150.5381	39	21		14						11	39	19		
Northwest	59.7958	150.0061	76	35		32	76		26		9	32	56	15		
Pedersen Glacier	59.8683	149.7217	114	72		95	52		114		72	65	36	70		
Quartz Bay	59.4978	150.5000	20	6		1						20	1	1		
Tonsi-Long I.	59.4214	150.6786	12	8		11							1	12		
Tonsini Bay	59.3208	150.8594	7	7								7				
Yukon I.	59.5417	151.4567	1	1			1									
		totals =	15,595	10,595	1,560	3,307	3,335	933	6,373	548	6,156	8,089	6,483	5,770	5,756	2,169

MAX	MEAN
15,595	10,595

95 % Confidence Interval	
9,993 =LOW	11,197 =HIGH

CV	COUNT	SD
2.90	965	306.77

1 = This haulout was surveyed by both Wynne and Olesiuk. N, mean, max, s.d. and other statistical values are combined and calculated only once.

Table 9. Comparison of counts between 1992 and 1996 harbor seal census surveys.

Location	Year	Mean	S.D.	C.V.	95 % Confidence Interval		Difference in 1996	No. seals in new locations	Net Increase
Area 1	1992	1419	136.37	9.61	1141 = Low	1697 = High	- 71 seals	0	- 71 seals
	1996	1348	68.29	5.06	1213 = Low	1484 = High			
Area 2	1992	1056	83.2	7.88	890 = Low	1221 = High	+ 796 seals	553	+ 243 seals
	1996	1852	85.23	4.6	1684 = Low	2021 = High			
Area 3	1992	2061	116.16	5.64	1832 = Low	2290 = High	+ 2,376 seals	677	+ 1699 seals
	1996	4437	156.43	3.53	4129 = Low	4745 = High			
Area 4	1992	1105	206.11	18.65	663 = Low	1547 = High	+ 1,139 seals	445	+ 694 seals
	1996	2244	234.68	10.46	1779 = Low	2709 = High			
Area 5	1992	695	82.8	11.91	527 = Low	863 = High	+ 18 seals	0	+ 18 seals
	1996	713	51.33	7.19	610 = Low	817 = High			

TOTALS		
1992 =	6,336	seals
1996 =	10,595	seals
	4,259	more seals in 1996
	-1,675	minus seals in new locations
	2,584	= net increase in 1996

Table 10. "Major" sites in each area, those with more than 100 seals in either 1992 or 1996.

Location	Latitude	Longitude	1996	1992	difference
Sanak I.	54.5000	162.8667	279	214	65
Sandman I.	54.7917	162.1750	61	211	-150
Simonof I.	54.9000	159.3333	71	159	-88
Cape Douglas Reef .	58.7606	153.2883	173	177	-4
Chankliut I.	56.1467	158.1328	131	32	99
Hallo Bay	58.4725	154.0142	144	0	144
Wide Bay	57.4611	156.1997	132	110	22
Augustine	59.3167	153.4939	470	573	-103
Shaw I.	58.9978	153.3778	309	0	309
Big River	60.6414	152.0222	164	146	18
Bradley R.	59.2022	151.1189	313	321	-8
McCarty Glacier	59.7192	150.2194	118	139	-21
Northwest Glacier	59.7958	150.0061	35	118	-83
Ugak I.	57.3756	152.2572	253	116	137
Sitkinak I.	56.5022	153.9714	269	324	-55
Tugidak I.	56.6044	154.4786	1345	770	575
Geese I.	56.7203	153.9258	156	100	56
Chirikof I.	55.8144	155.5544	176	243	-67
Kalsin Bay	57.6447	152.3614	104	37	67
Mt. Myrtle I.	57.2161	154.5906	194	53	141
			4599	3753	846

No. sites increasing = 11
No. sites decreasing = 7
No. sites same = 2

Table 11. The number of seals counted at each site for the Copper River Delta, Orca Inlet, Middleton and Kayak Islands.

Location	Latitude	Longitude	MAX	MEAN	8/27/96	8/28/96	8/31/96	9/1/96	9/2/96	9/3/96
Copper River Delta	60.42111	144.8997	18	18	18					
Copper River Delta	60.29083	145.0886	180	119	164	180		127	11	111
Copper River Delta	60.29583	145.0875	145	106	145			52	118	109
Copper River Delta	60.30333	145.0797	852	443	223	477	234	852	239	632
Copper River Delta	60.30972	145.0536	766	208	18	107	129		766	19
Copper River Delta	60.32861	145.0433	359	249	131	359			295	209
Copper River Delta	60.33417	145.0367	135	75	135	122	27		22	68
Copper River Delta	60.33944	145.0214	138	83		138				28
Copper River Delta	60.44139	144.8861	78	78						78
Copper River Delta	60.44861	144.8597	51	51						51
Copper River Delta	60.4575	144.8278	66	66						66
Copper River Delta	60.55917	144.8636	35	35						35
Copper River Delta total			2823	1530						
Eyak R.	60.40806	145.7261	26	21			15	26		
Eyak River total			26	21						
Kayak I.	59.78667	144.5567	52	45				37	52	
Kayak I.	59.85056	144.4789	13	12				10	13	
Kayak I.	59.87389	144.5589	117	117				117		
Kayak I.	59.89806	144.3903	29	29				29		
Kayak Island total			211	202						
Middleton I.	59.38944	146.3464	194	120		46			194	
Middleton I.	59.39306	146.3764	642	493		344			642	
Middleton I.	59.39556	146.4008	267	246		225			267	
Middleton I.	59.40917	146.3119	230	185		139			230	
Middleton I.	59.43028	146.2769	44	33		22			44	
Middleton I.	59.43556	146.2694	351	221		91			351	
Middleton I.	59.46389	146.2711	88	86		88			83	
Middleton Island total			1816	1383						
Orca Inlet	60.43306	146.0669	141	117			92	141		
Orca Inlet	60.44667	146.3458	191	113	21		128	191		
Orca Inlet	60.46583	146.0575	130	44	3	130	13	29		
Orca Inlet	60.50111	145.9994	28	27	28		27	25		
Orca Inlet	60.53389	145.8625	55	47	55	49	32	51		
Orca Inlet total			545	347						

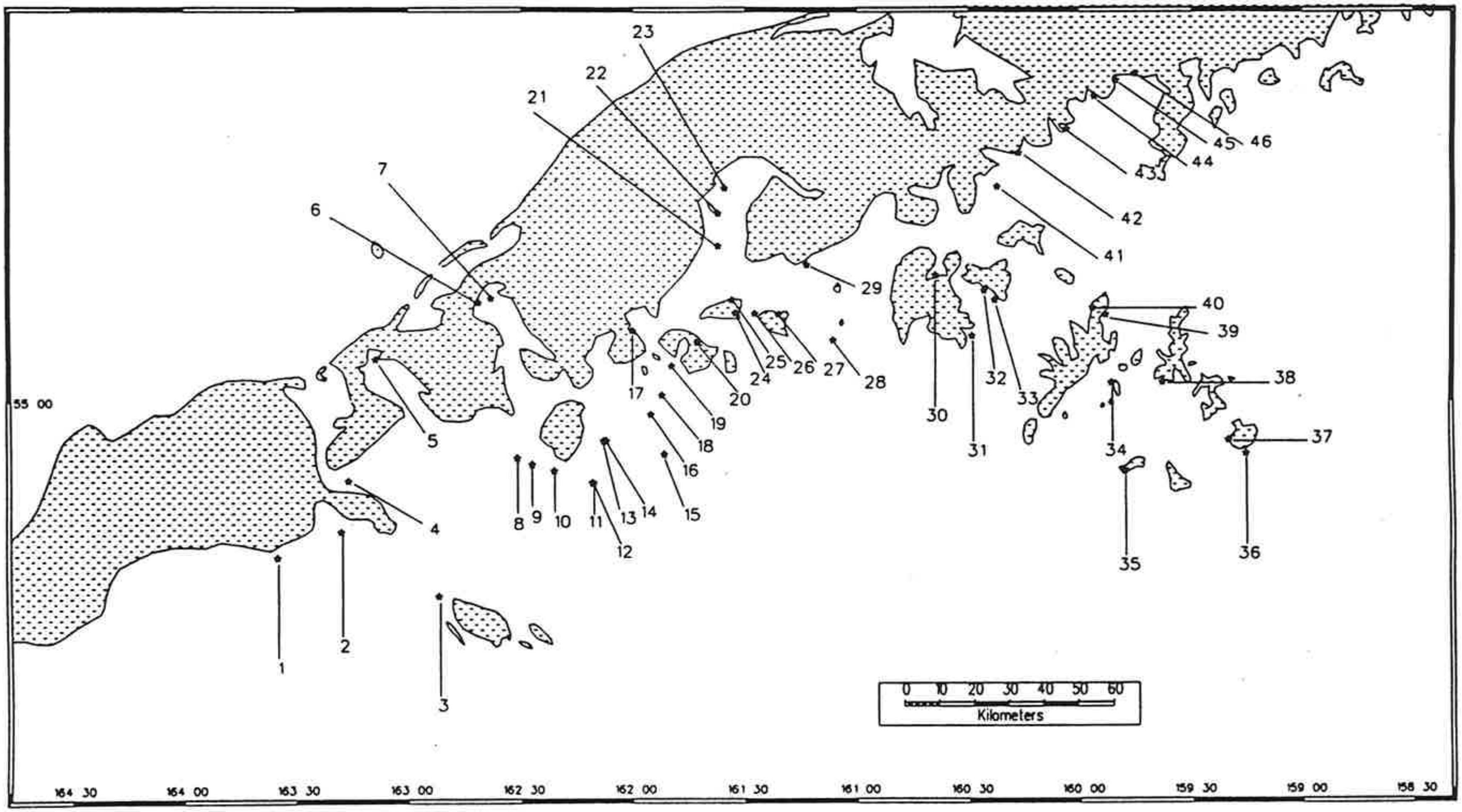

Figure 1. **Harbor seal locations for area 1 (south side of the Alaska Peninsula including the Shumigan Islands) surveyed in 1996. Refer to Table 2 for site names and positions.**

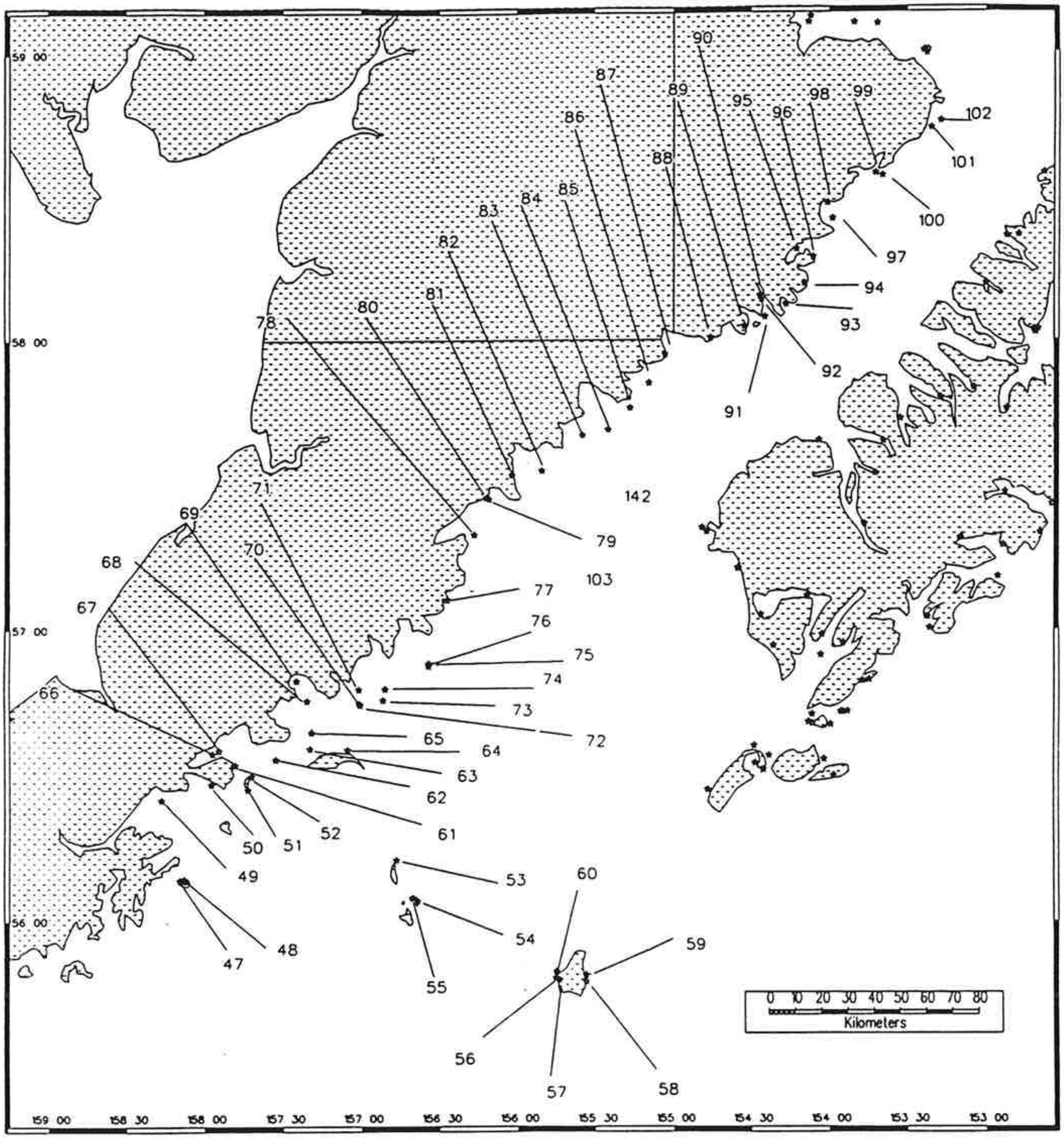

Figure 2. **Harbor seal locations for area 2 (south side of the Alaska Peninsula including the Semidi Islands and Chirikof Islands) surveyed in 1996. Refer to Table 2 for site names and positions.**

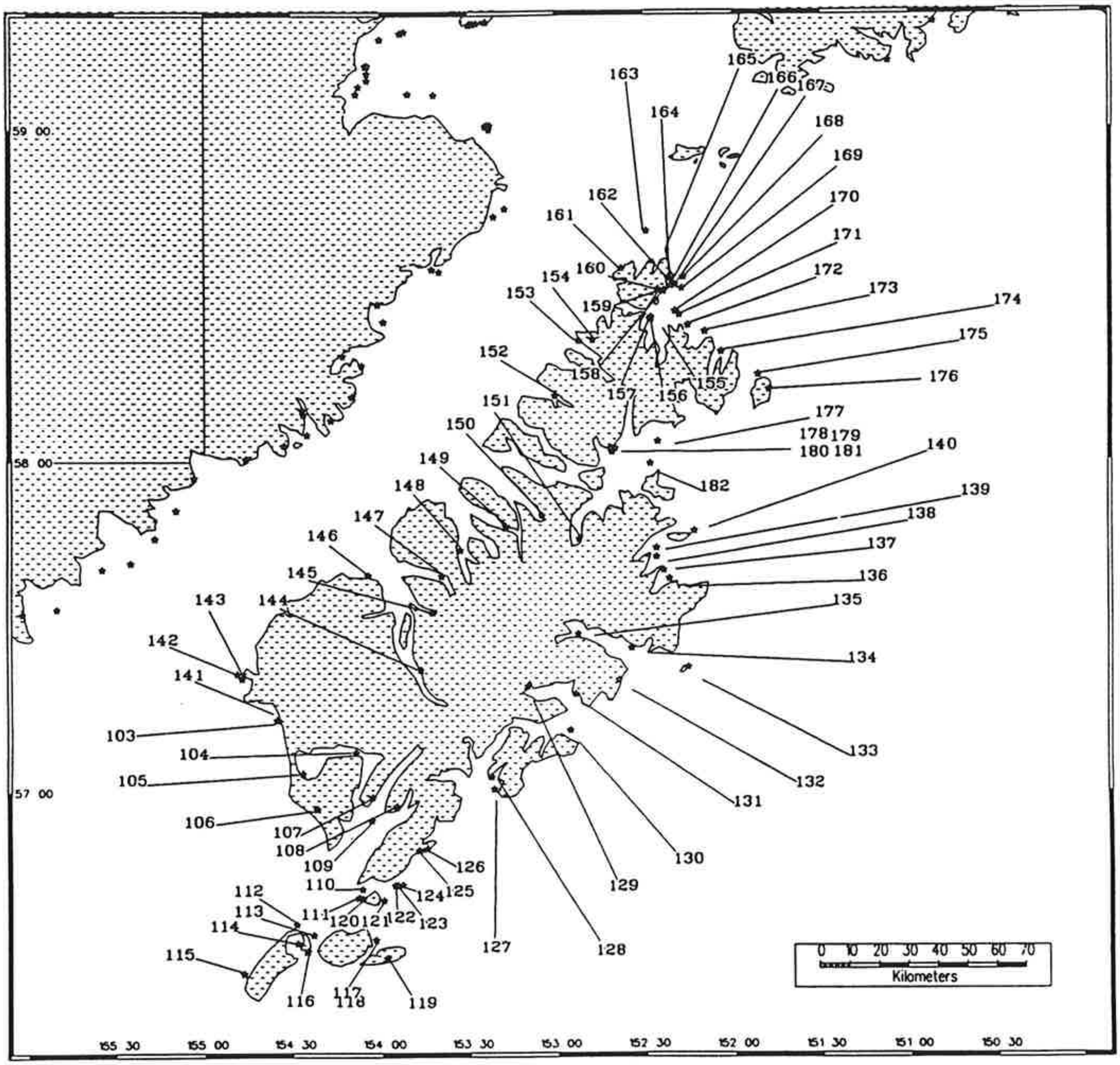

Figure 3. Harbor seal locations for area 3 (Kodiak Archipelago) surveyed in 1996. Refer to Table 2 for site names and positions.

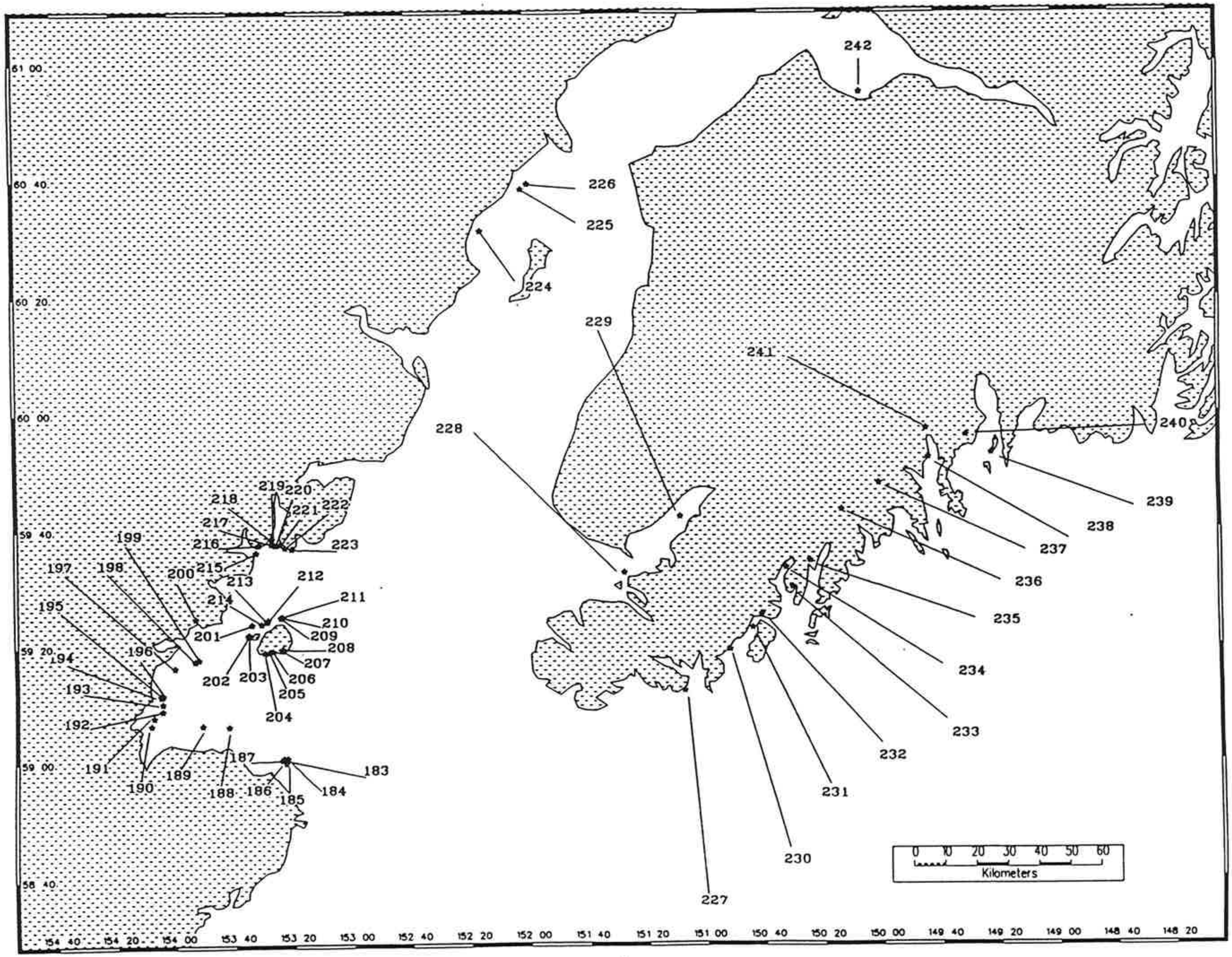

Figure 4. Harbor seal locations for areas 4 and 5 (Cook Inlet and the Kenai) surveyed in 1996. Refer to Table 2 for site names and positions.

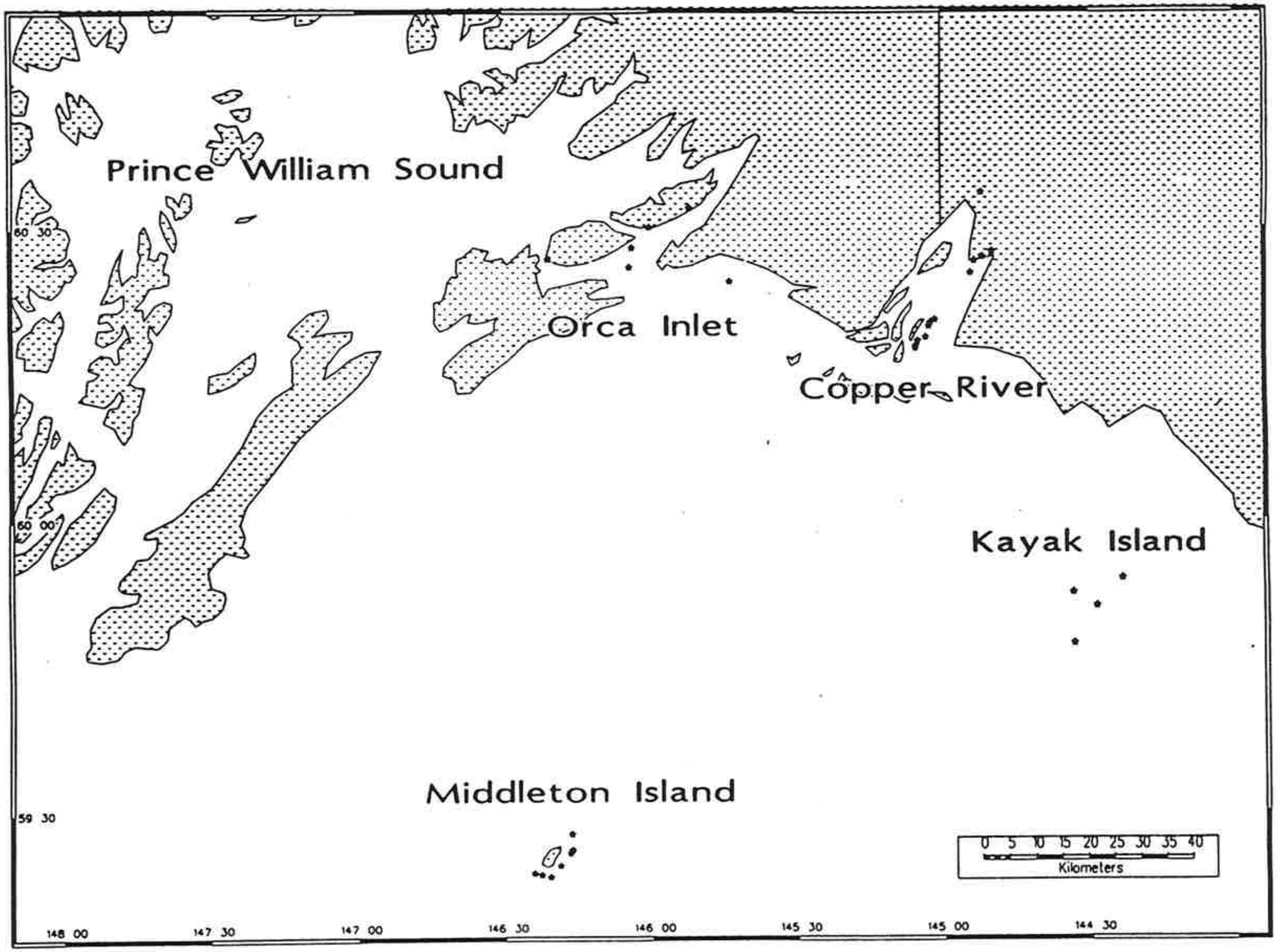

Figure 5. **Harbor seal locations for the area including the Copper River Delta, Orca Inlet, Kayak Island and Middleton Island surveyed in 1996.**

A CORRECTION FACTOR ESTIMATE FOR THE PROPORTION OF HARBOR SEALS MISSED ON SAND BAR HAULOUTS DURING MOLT CENSUS SURVEYS IN 1996 NEAR CORDOVA, ALASKA

David E. Withrow and Thomas R. Loughlin

National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington 98115

Abstract

Thirty-four harbor seals, *Phoca vitulina*, were captured and equipped with radio transmitters to determine the relative proportion of seals at sea that are not counted during low tide aerial surveys. Of these, 12 were males and 22 were females which were comprised of 29 adults, 3 sub-adults, and 2 yearlings. Females showed a slight tendency to be further along than males in the stage of their molt. Aerial surveys were flown during the molt period in mid-August and early September to record the percentage of tagged seals hauled out. Most seals remained in Orca Inlet (near Cordova, Alaska), where they were tagged or nearby (within 4-6 km). A few seals traveled to other locations (65-75 km away) and returned. Eleven replicate aerial surveys were flown and the mean percent number of tagged seals hauled out each day was 53% (SD=13%, CV=0.24). A correction factor of 1.90, the reciprocal of 53%, was computed. This correction should only be applied to those areas similar in geography and phenology and censused during similar time periods.

Introduction

Harbor seals (*Phoca vitulina*) are censused from aircraft by photographing those on land during the molt period (August/September). These surveys miss an unknown number of animals that are at sea during the survey period. This paper reports on the third year of a multi-year study to determine a correction factor based on the relative proportion of seals that are at sea and thus are not counted during the surveys. This correction factor will then be applied to the count data minimum to determine a more accurate estimate of harbor seal abundance in Alaska.

Harbor seals inhabit temperate and sub-arctic coastal and estuarine waters from Baja California north to Cape Newenham, Alaska, and the Pribilof Islands. They are medium-sized phocid seals which range in color from silver-white with black spots (light phase) to black with silver-white spots (dark phase; Shaughnessy and Fay 1977, Hoover-Miller 1994). The largest proportion of light phased seals occurs in the Gulf of Alaska region with increasing proportion of dark phased animals to the west and south (Shaughnessy and Fay 1977). Harbor seals haul out on rocks, reefs, beaches, and drifting glacial ice. They are considered non-migratory; however, tide, weather, time of day, season and food availability all contribute to their haulout patterns.

There are two annual peaks in haulout behavior: one during May/June (pupping) and the other during August/September (molt) when maximum numbers occur on land. Surveys generally occur during one or both of these haul out periods. Researchers in Washington and Oregon primarily census during the pupping season (Huber et al. 1992). In Alaska, however, it was agreed that census surveys should be conducted during the molt because the window when most seals haul out on land is reduced and greater numbers of seals are believed to haul out then (Ferrero and Fowler 1992).

Previous Correction Factor Studies

In 1994, we conducted the first correction factor study on rocky substrate in southeast Alaska (Withrow and Loughlin 1995). Our primary haulout site was a small, rocky island (54°57.83 N, 132°46.78 W) with a few gravel beaches exposed only at low tide. These gravel beaches were preferred areas, but ample rocky haulout space remained, even during the highest tidal conditions. The mean percent number of tagged seals hauled out each day during low tide was 57.5%. This resulted in a correction factor of 1.74. We stated that this correction should be applied only to those areas similar in geography and phenology.

In 1995 and 1996, we chose a sand-bar substrate, which was completely submerged during low tide near Cordova, Alaska, adjacent to Prince William Sound. We worked primarily in Hawkin's Cutoff (60°27.052 N, 146°19.577 W) in 1995. During the normal molt census surveys, the weather was marginal, at best. The mean percent number of tagged seals hauled out was only 40% and the resulting correction factor was 2.50 (Withrow and Loughlin 1996). The Alaska Department of Fish and Game (ADF&G) recorded the presence of our seals during their aerial surveys 2 weeks earlier, under much more favorable conditions. ADF&G surveys also covered most of Prince William Sound, whereas our surveys were concentrated primarily within 40-50 km of the tagging location. During this time period, the mean percent number of tagged seals hauled out was 66.7%, resulting in a correction factor of 1.50. We stated (Withrow and Loughlin 1996) the correction factor values of 1.50 and 2.50 probably represent the extremes with 1.50 being the preferred correction factor, even though the hauling pattern data were collected earlier than other NMML molt surveys. For at least Prince William Sound and perhaps for other areas, ADF&G has found that surveys conducted in mid-August yield higher counts than surveys conducted in later August or early September (Frost et al. 1996). The 2.5 correction factor may at least suggest an upper bound and may give us a better indication of possible count adjustments, if molt census surveys were conducted under similar marginal weather conditions.

For 1996, we decided to repeat our efforts in the Cordova area in order to reduce the variance and increase the precision of the 1995 correction factor estimates.

Methodology

Capture and tagging operations this year occurred throughout Orca Inlet (60°27.052 N, 146°19.577 W; Fig. 1) from 9 to 17 August 1996. The scientific crew were from several different affiliations (Table 1).

Harbor seals were captured by entanglement in gillnets placed near the haulout sites. These methods have been used by ADF&G (Frost and Lowry 1994) and NMML (Withrow and Loughlin 1995) and are continually modified and improved to adjust to changing physical conditions relative to the particular capture site. The ADF&G provided the skiffs, net, and some personnel for the project. The gillnet was approximately 100 m long and 7.4 m deep. Mesh size openings ranged from 10-15 cm (20-30 cm stretch mesh). The net was set as close as possible to the haulout sites using a 6 m Boston Whaler equipped with specially designed hardware to set the net while traveling at high speeds. Initially this boat would approach the haulout site at medium speed from behind or to the side of the island so as not to be detected by the seals. Upon reaching the site, a crew member wearing a dry suit and fins would jump into the water with one end of the net. He would quickly secure his end to boulders on shore as the boat raced to the other end of the haulout site. The seals became entangled as they went into the water in response to the setting of the net. Another 5 m skiff and a 4 m inflatable raft followed to tend the net. When the seals became entangled, they were pulled into one of the skiffs, cut free from the gillnet and placed into a hoop net constructed with a rubber hose and 1 cm mesh soft nylon webbing. When all the entangled seals were transferred to hoop nets, the tangle net was retrieved and the seals taken to shore for processing.

All seals were physically restrained during handling and tagging; no chemical sedation was required. Seals were initially given an external examination which included recording mass, standard length, sex, age class, stage of molt, and noting any external scars, wounds, or parasites. Approximately 50 cc of blood was drawn from the extradural intervertebral vein to assess health and condition. On some animals, a whisker was taken for stable carbon isotope analysis. The seals were then tagged on the hind flipper with a Temple cattle-ear tag (1 x 1.5 x 5.0 cm) with a VHF transmitter attached (Advanced Telemetry Systems Inc. model 201, 164 Mhz). Weight of the tag and transmitter was approximately 25 g. A small 0.7 cm diameter biopsy punch was taken from the left rear flipper (used for mitochondrial DNA studies) and the Temple tag was clipped in place through this small hole. A small plastic, powder-blue, All Flex tag (1.5 x 4.5 cm) was clipped to the right rear flipper. Seals were released immediately after tagging. A list of radio frequencies used, animal identification numbers, samples taken, and other information appear in Table 2.

We attempted to place two ATS data collection computers (DCC) and receivers on shore to record when tagged seals were hauled out. Unfortunately, the closest spit of land (60° 23.89 N, 146° 08.24 W; Fig. 1) to the main tagging location (site four; 60° 25.91 N, 146° 04.14) which was about 3-3.5 km away, proved to be too great a distance for the DCC to detect animal presence reliably. The second unit, placed near a group of seals close to the town of Cordova (site one, 60° 32.36 N, 145° 52.00 W), had a chip failure and all data were lost. Therefore, we have no haul out behavioral data to present in this paper.

Aerial surveys were flown from 19 to 26 August by the ADF&G and from 27 August to 2 September 1996 by NMML. These surveys were flown after release of the transmitter-equipped seals to determine the proportion of seals at sea which were not hauled out (or visually detectable using photography) during the molt census period. We utilized a single-engine Cessna 185 equipped with floats for our daily surveys which were conducted as close to low tide as possible. The study area is illustrated in Figure 1. Two antennae were mounted on the wing struts, one pointing forward and to the left and the other pointing forward and to the right. An ATS receiver equipped with an A/B/Both switch was used to determine which side of the aircraft the seals were located. During flight, one biologist listened to the receiver with headphones and recorded when and where seals were found while a second biologist took photographs and estimated the number of seals hauled out. A portable computer interfaced to a Global Positioning System (GPS) and moving-map-display software provided real-time flight track and harbor seal location data. Due to extremely bad weather, the final reconnaissance flight was made on 14 September to estimate the number of seals and to retrieve the DCC and other equipment.

During tagging, the stage of molt for each seal was estimated. The categories used were pre-molt, early mid-molt, mid-molt, late mid-molt and post-molt. These categories were assigned a numerical value: pre-molt received a value of 1, early mid-molt a value of 2 , mid-molt a value of 3, late mid-molt a value of 4 and post molt a value of 5. Males and females were then scored and a mean value determined to estimate the average stage of molt during the tagging period. This was also done for age class (adult, sub-adult, or yearling).

Results

A total of 34 seals were captured and equipped with transmitters. Of these, 12 were males and 22 were females which were comprised of 29 adults, 3 sub-adults and 2 yearlings (Table 2). Capture operations took place in Orca Inlet, but unlike the 1995 study where most seals came from Hawkin's Cutoff, seals were taken from several locations throughout the inlet (Fig. 1).

During tagging, the stage of molt for each seal was estimated. Males had an average molt score of 3.8 and females 3.9 (Table 2). All adult seals combined also had a mean molt value of 3.9, sub-adult 3.8, and the 2 yearlings averaged 4.0 (Table 2).

During ADF&G surveys (19-26 August), 31 of the 34 tagged seals were relocated at least once from the air (Table 3). During NMML surveys (27 August to 2 September), 28 of the 34 tagged seals were relocated (Table 4). Only one seal, frequency 164.843, was not detected by either group.

The daily percent number of tagged seals hauled out was calculated by dividing the number of tagged seals hauled out by the number of seals detected at least once during all aerial surveys. Total sample size (N) used for ADF&G and NMML surveys was 31 and 28, respectively.

Five seals were relocated during ADF&G surveys (immediately after tagging) which were far from Orca Inlet. Some seals moved as far as 65-75 km away and all but two were also relocated back in or near Orca Inlet during their flight series (Table 6). These seals were beyond the 40-50 km detection range we generally fly when relocating seals. It is extremely unlikely that NMML surveys would have detected these seals. In order to more fairly compare results between our surveys, ADF&G counts were recalculated, subtracting these distant animals, for some of the calculations.

The mean number of tagged seals hauled out each day during ADF&G surveys was 17.5 (range 12-25) over their entire survey area (Prince William Sound) and was 16.3 (range 11-23) in the area surrounding Orca Inlet (with distant seals removed; Table 3). The mean number of tagged seals hauled out each day during NMML surveys was 14.8 (range 10-19) in the area surrounding Orca Inlet (Table 4). The daily percentage of tagged seals hauled out ranged from 39% to 81% with a mean of 56% during ADF&G surveys of Prince William Sound. In the area surrounding Orca Inlet, the daily percentage of tagged seals hauled out ranged from 35% to 74% with a mean of 53% (Table 3). During NMML surveys, the daily percentage of tagged seals hauled out ranged from 36% to 68%, also with a mean of 53% (Table 4). These daily percentages for both ADF&G and NMML surveys were combined and an overall mean calculated. For all seal sightings, the overall mean was 55% and the correction factor, the reciprocal of the mean, is 1.82 (Table 5). For sightings in the normal survey range around Orca Inlet (i.e., distant seals removed), the overall mean was 53%, SD=0.13, and CV=0.24, which translates into a correction factor of 1.90 (Table 5).

Discussion

Cordova is a small town with a large salmon gillnet fishing fleet, which fishes in the Copper River Delta and surrounding areas. Vessel traffic is quite high with constant fishery openings, closings, runs to town for fuel and to drop off catches at various processors and canneries. Orca Inlet, where the seals primarily haul out, is composed of several sandy bars which are completely submerged at high tide.

The study was repeated in the Orca Inlet area in 1996 for a variety of reasons, but primarily to determine a reliable correction factor (as opposed to determining outer bounds), to look more closely at seal movement within and beyond the study area, and to deal with seals in areas of high vessel traffic (last year's study site at Hawkin's Cut-off in northern Orca Inlet was quite isolated).

Molt Phenology

Thompson and Rothery (1987) noted that females completed their molt an average of 7 days earlier than immature males and 19 days earlier than mature males. Two years ago in southeast Alaska, we also noticed that females were further along in the molting process than were most males (Withrow and Loughlin 1995). Male seals spent more time hauled out (27.1%) on average than did females (9.7%) or pups (7.0%).

In 1995, for seals tagged at Hawkin's Cut-off, females showed a slight tendency to molt sooner with a mean molt score of 2.3 compared to males with a mean score of 1.9, using a three criteria scoring system (Withrow and Loughlin 1996). In 1996, we used a five criteria scoring system (Table 2). There was still a tendency for females and young to be further along in the molt process by only the slightest of margins and certainly not significant. Males had an average score of 3.8 and females 3.9 (Table 2). When seals were combined by age class, there was still very little difference. Adult seals had a mean value of 3.9, sub-adult 3.8, and the 2 yearlings averaged 4.0 (Table 2).

Haulout Behavior Data

Many researchers have noted that seals haul out in greatest numbers in the absence of high winds, heavy rains, and/or disturbance (Fisher 1952, Bishop 1967, Knudtson 1974, Johnson 1976, Calambokidis et al. 1978, Streveler 1979, Allen et al. 1980, Everitt and Braham 1980, Sullivan 1980). Tidal influences are greatest on gently sloping substrates, such as tide flats, where minor tidal changes affect large surface areas (Hoover-Miller 1994).

Last year we noted that haulout behavior was strongly influenced by tide. Most seals hauled out within an hour of low tide and remained hauled out for several hours. Often, a few seals would remain on the bar after it became almost totally submerged (Withrow & Loughlin 1996). Unfortunately, this year we had difficulties with our remote ATS data collection computers (DCCs). We first tried to install one unit across from Site 4 where most seals were captured (Fig. 1). The closest spit of land was about 3-3.5 km away. This proved to be too great a distance for the DCC to detect animal presence reliably. The ATS receivers had little problems detecting the signals, but the DCC could not distinguish their sounds from the ambient. The second unit was placed near a group of seals close to the town of Cordova (Site one, Fig. 1). This DCC initially worked fine, but sometime during the next month, a chip had failed and all data were lost. Therefore, we have no new haulout behavioral data to present in this paper, but subjectively, no differences were noted from last year.

Correction Factor Analysis

Many census studies for harbor seals are designed to determine a minimum population estimate for the particular area of interest. It is unknown how these minimum estimates correlate with the true size of the population. Withrow and Loughlin (1995), provided a table of earlier tagging studies, most of which suffered from small sample sizes and were not designed specifically to correct specific census estimates. Boveng (1988) formulated a "best guess" correction factor of 1.4 to 2.0 for the number of harbor seals along the U. S. west coast. Huber et al. (1992) calculated correction factors ranging from 1.5 to 1.8 for the counted population during pupping in Oregon and Washington. Withrow and Loughlin (1995) calculated a correction factor of 1.74 for harbor seals in southeast Alaska, hauled out on rocky outcroppings and islands not completely covered by water at high tide. Last year, Withrow and Loughlin (1996) reported two correction factors for Hawkin's Cut-off, at the north end of Orca Inlet. This area is characterized as a sandy bar which is completely covered at high tide. The correction was 1.50 using data from ADF&G surveys during excellent weather conditions immediately following tagging. Several weeks later, NMML flew surveys during marginal weather conditions in September and obtained a correction factor of 2.50. Withrow and Loughlin (1996) reported the 1.50 and 2.50 correction factors as probable upper and lower bounds for surveys conducted during excellent and very poor weather conditions.

Generally, we wait approximately 2 weeks after tagging before we begin the aerial reconnaissance in order to allow the seals to reacclimate after the tagging process. This year, ADF&G again offered to listen for our seals during their census flights, immediately following the completion of tagging. These surveys were invaluable in that they not only doubled our sample size but covered a large area that would not ordinarily have been sampled. They relocated seals tagged in Orca Inlet at several sites up to 65-75 km away (Table 6). Similar results were reported last year (Withrow and Loughlin 1995). Most seals did return, at least occasionally, to their original tagging locations. Seals appeared to move freely throughout the inlet, but most had preferred sites.

ADF&G flew six replicate surveys and relocated, on average, 56% of tagged seals (Table 3). With distant seals removed (those seals that were not close to Orca Inlet and would not normally have been detected by NMML reconnaissance surveys), the mean daily percent of tagged seals detected was 53%. NMML flew five replicate surveys and also detected an average of 53% of the tagged seals (Table 4). Data from ADF&G and NMML surveys were combined and for all seals, the overall mean percent seen was 55%. The resulting correction factor is 1.82. However, we feel the data set with distant seals removed is more appropriate. The overall mean daily percent of tagged seals detected, using ADF&G and NMML data with distant seals removed, was 53%, SD=0.13 and CV=0.24 (Table 5). This results in a correction factor of 1.90. This value is also between the 1.50 and 2.50 correction factor bounds determined last year.

Therefore, we believe the 1.90 correction factor accurately reflects the proportion of seals not hauled out during molt surveys, in the Orca Inlet region for seals utilizing sand bar haul outs. Again, we stress that this correction should only be applied to those areas similar in geography, phenology, and censused during similar time periods. Seals in other geographic areas or other types of haulout sites, may behave quite differently. Caution should be exercised initially so that this correction factor is not applied too broadly. Our future work will focus on other areas of Alaska and on different substrates (i.e., glacial ice) where tidal and environments influences may be different.

Acknowledgments

We are grateful for the expertise, hard work and long hours of all those people listed in Table 1. Alaska Department of Fish and Game provided skiffs and capture equipment. Mary Ann Bishop of the Copper River Delta Institute, U.S. Forest Service, graciously let us borrow one of their Boston Whalers for the entire duration of capture operations and the Prince William Sound Science Center lent us a small inflatable to recover our DCC in mid-September. Steve Ranney and Gail Ranney from Fishing and Flying piloted the Cessna 185 on floats (N6JV). Jack Cesarone assisted in both phases of the operation and counted seals from the air. Anne York offered statistical assistance. A special thanks to Kathy Frost (ADF&G) and Steve Ranney (Fishing and Flying) for listening and recording our tagged seals during their flights. Their help was invaluable and our success was directly related to their efforts. We appreciate the assistance of all these people.

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Table 1. Key personnel, affiliation, and survey dates

NAME	AFFILIATION	PROJECT	DATES
Dave Withrow, PI	NOAA, NMFS, National Marine Mammal Laboratory	Tagging	9-17 Aug. '96
		Aerial	27 Aug.- 2 Sept. '96
Jack Cesarone	NOAA, NMFS, National Marine Mammal Laboratory	Tagging	9-17 Aug. '96
		Aerial	27 Aug.- 2 Sept. '96
Dennis McAllister	Alaska Department of Fish and Game, Anchorage	Tagging	9-17 Aug. '96
Kate Wynne	Alaska Sea Grant, University of Alaska, Kodiak	Tagging	9-12 Aug. '96
Barbara Mahoney	NOAA, NMFS, Anchorage Area Office	Tagging	12-17 Aug. '96
Jennifer Burns	University of Alaska, Fairbanks	Tagging	9-17 Aug. '96
Robin Westlake	NOAA, NMFS, Southwest Fisheries Science Center	Tagging	13-17 Aug. '96
Alexander Boiko	Kamchatka Institute of Ecology and Nature Management;	Tagging	9-17 Aug. '96
	Russian Fisheries Agency, Kamchatrybvod		9-17 Aug. '96
Nikolay Pavlov	Kamchatka Institute of Ecology and Nature Management;	Tagging	9-17 Aug. '96
	Russian Fisheries Agency, Kamchatrybvod		9-17 Aug. '96
Kathy Frost	Alaska Department of Fish and Game, Fairbanks	Aerial	19-26 Aug. '96
Steve Ranney	Pilot, Fishing & Flying, Cordova	Aerial	19-26 Aug. '96

Table 2. List of seals tagged, radio frequencies used, animal ID and other data collected during the 1996 Orca Inlet harbor seal correction factor study.

DATE	SEAL NO.	FREQUENCY	SEX	AGE	BLUE TAG	BLOOD	GENETICS	WHISKERS	MOLT
8/9/96	1-216	164.216	M	Adult	201	X	XX	X	3
8/9/96	2-233	164.233	F	Adult	202	X	XX	X	5
8/9/96	3-254	164.254	M	Adult	203	X	XX	X	3
8/9/96	4-273	164.273	F	Adult	204	X	XX	X	3
8/9/96	5-294	164.294	M	Adult	205	X	XX	X	5
8/9/96	6-313	164.313	F	Adult	206	X	XX	X	3
8/11/96	7-374	164.374	F	Adult	209	X	XX	X	4
8/11/96	8-336	164.336	F	Adult	207	X	XX	X	3
8/11/96	9-353	164.353	F	Sub-Adult	208	X	XX	X	3
8/11/96	10-394	164.394	M	Adult	210	X	XX	X	3
8/13/96	12-414	164.414	F	Sub-Adult	212	X	XX	X	3
8/12/96	11-434	164.434	F	Adult	211	X	XX	X	5
8/13/96	13-454	164.454	F	Sub-Adult	213	X	XX	X	5
8/14/96	14-473	164.473	F	Yearling	214	X	XX	X	5
8/14/96	15-494	164.494	M	Yearling	215	X	XX	X	3
8/14/96	16-516	164.516	F	Adult	216	X	XX	X	5
8/14/96	17-534	164.534	M	Adult	217	X	XX	X	3
8/14/96	18-555	164.555	F	Adult	219	X	XX	X	3
8/14/96	19-575	164.575	F	Adult	218	X	XX	X	3
8/14/96	20-592	164.592	F	Adult	220	X	XX	X	5
8/14/96	21-613	164.613	F	Adult	221	X	XX	X	3
8/15/96	22-635	164.635	F	Adult	222	X	XX	X	5
8/15/96	23-653	164.653	M	Adult	223	X	XX	X	4
8/15/96	24-673	164.673	F	Adult	224	X	XX	X	5
8/15/96	25-696	164.696	M	Adult	225	X	XX	X	3
8/15/96	26-714	164.714	F	Adult	226	X	XX	X	5
8/15/96	27-754	164.754	F	Adult	227	X	XX	X	5
8/15/96	28-774	164.774	F	Adult	228	X	XX	X	4
8/15/96	29-794	164.794	M	Adult	229	X	XX	X	3
8/16/96	30-814	164.814	M	Adult	230	X	XX	X	5
8/16/96	31-834	164.834	F	Adult	231	X	XX	X	5
8/16/96	32-854	164.854	M	Adult	232	X	XX	X	3
8/17/96	33-874	164.874	M	Adult	233	X	XX	X	2
8/17/96	34-893	164.893	F	Adult	234	X	XX	X	5

MOLT	STAGE
1=	PRE
2=	EARLY MID
3=	MID
4=	LATE MID
5=	POST

MEAN MOLT SCORE		
Adult	29	3.9
Sub-Adult	3	3.8
Yearling	2	4.0
Males	12	3.9
Females	22	3.9

Table 3. The number of tagged harbor seals relocated during the ADF&G aerial reconnaissance surveys. Distant seals are seals not close to the survey area (signified by a shaded box). These seals probably would not have been detected during the NMML surveys of Orca Inlet.

SEX	FREQUENCY	08/19/96	8/21/96	8/22/96	8/23/96	8/24/96	8/26/96
M	164.216	1	1		1	1	1
F	164.233					1	
M	164.254	1	1		1		1
F	164.273	1	1	1			1
M	164.294	never seen					
F	164.313		1				1
F	164.374	1	1		1	1	1
F	164.336	1	1	1	1		
F	164.353	1	1		1		
M	164.394	1	1		1	1	1
F	164.414			1			1
F	164.434	1	1	1	1		
F	164.454	1	1				
F	164.473	1					
M	164.494	1		1			
F	164.516	1	1	1	1	1	1
M	164.534	1	1		1	1	1
F	164.555	1				1	
F	164.575	1	1	1	1	1	
F	164.592	1					
F	164.613	1					
F	164.635	1	1	1	1	1	1
M	164.653	1		1	1		1
F	164.673	1				1	
M	164.696	1	1	1		1	1
F	164.714			1		1	1
F	164.754	1	1			1	1
F	164.774					1	
M	164.794	1	1	1	1		1
M	164.814		1		1	1	
F	164.834	never seen					
M	164.854	1	1		1	1	
M	164.874	1			1	1	1
F	164.893	never seen					

Total	25	19	12	16	17	16
% seen	0.81	0.61	0.39	0.52	0.55	0.52

overall mean % 0.56

31 = number of seals detected at least once.
3 = number of seals never detected
34 = total seals tagged

Total (-distant seal	23	19	11	15	16	14
% seen	0.74	0.61	0.36	0.48	0.52	0.45

overall mean % 0.53

Table 4. The number of tagged harbor seals relocated during the NMML aerial reconnaissance surveys.

SEX	FREQUENCY	8/27/96	8/28/96	8/31/96	9/1/96	9/2/96
M	164.216			1	1	1
F	164.233	never seen				
M	164.254	1	1	1	1	1
F	164.273	1	1	1	1	
M	164.294	1		1	1	
F	164.313	never seen				
F	164.374	never seen				
F	164.336				1	1
F	164.353		1		1	
M	164.394		1	1	1	
F	164.414			1		
F	164.434		1		1	
F	164.454				1	
F	164.473		1			
M	164.494	never seen				
F	164.516	1				
M	164.534	1	1	1	1	1
F	164.555				1	
F	164.575	1	1			
F	164.592					1
F	164.613	1	1	1	1	1
F	164.635	1		1	1	
M	164.653		1	1	1	1
F	164.673			1		1
M	164.696		1	1	1	
F	164.714	never seen				
F	164.754			1		
F	164.774			1	1	1
M	164.794		1	1	1	1
M	164.814	1	1	1	1	1
F	164.834	never seen				
M	164.854	1	1	1	1	1
M	164.874		1			
F	164.893		1			

Total	10	16	17	19	12
% seen	0.36	0.57	0.61	0.68	0.43

overall mean %	0.53

28 = number of seals detected at least once
6 = number of seals never detected
34 = total seals tagged

Table 5. Correction Factor (CF) calculations using the average of the daily mean percentage of tagged seals detected from both the ADF&G and NMML aerial reconnaissance surveys. The reciprocal of this average is the correction factor. The calculations with the distant seals removed is our best estimate (CF = 1.90).

all surveys combined daily mean percent detected {+ distant seals}
0.36
0.57
0.61
0.68
0.43
0.81
0.61
0.39
0.52
0.55
0.52

overall		
Mean %	SD	CV
0.55	0.13	0.24

Correction Factor =
1.82

all surveys combined daily mean percent detected {- distant seals}
0.36
0.57
0.61
0.68
0.43
0.74
0.61
0.35
0.48
0.52
0.45

overall		
Mean %	SD	CV
0.53	0.13	0.24

Correction Factor =
1.90

Table 6. Seal number, frequency, sex, age class, date and location of distant seals (those not close to the original tagging location) relocated during the ADF&G surveys.

SEAL NO.	FREQUENCY	SEX	AGE	19-Aug	21-Aug	22-Aug	23-Aug	24-Aug	26-Aug
3-254	164.254	M	Adult	Orca	-----	Orca	-----	——	Stockdale
9-353	164.353	F	Sub-Adult	Stockdale	Chalmers	-----	-----	-----	-----
20-592	164.592	F	Adult	Applegate	-----	-----	-----	-----	-----
22-635	164.635	F	Adult	Double	Orca	Orca	-----	Montague	Chalmers
23-653	164.653	M	Adult	-----	Naked	Naked	-----	-----	Orca

Location Code	Location	Distance from Orca Inlet
Apple	Applegate Rocks	41 nm
Chalmers	Port Chalmers	38 nm
Double	Double Bay	13 nm
Montague	Montague Island	30+ nm
Naked	Naked Island	41 nm
Orca	in/near Orca Inlet	-----
Stockdale	Stockdale Harbor	35 nm

----- = seal not detected that flight

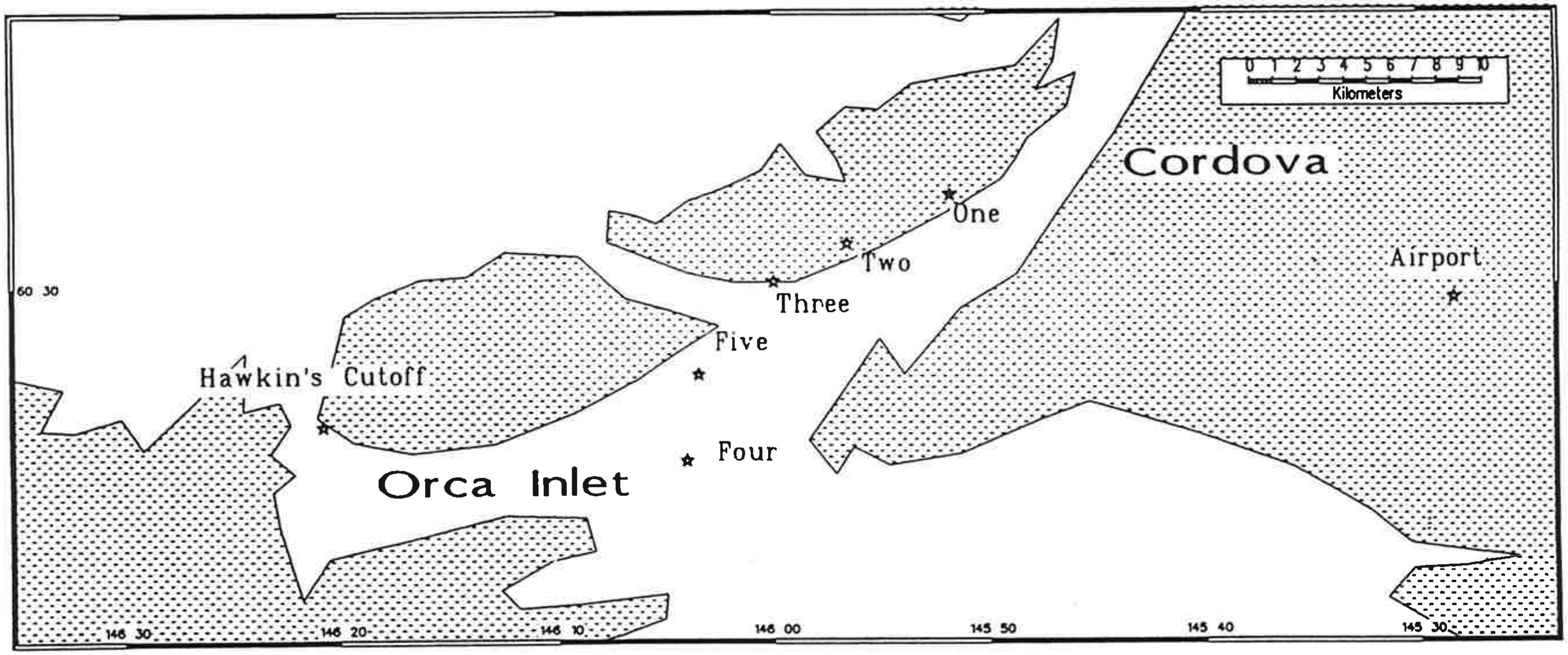

Figure 1. Chart of study area and seal capture locations.

ANNUAL REPORT OF THE NORTH PACIFIC HUMPBACK WHALE FLUKE PHOTOGRAPH COLLECTION, THROUGH NOVEMBER 1996

Sally A. Mizroch and Melissa S. Dolan

National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington, 98115

Abstract

The second Workshop on the Estimation of Calf Mortality in North Pacific Humpback Whales (*Megaptera novaeangliae*) was held at the National Marine Mammal Laboratory (NMML) from 25 to 27 November 1996. Papers were presented on survey methodology, and workshop participants Gabriele and Straley agreed to take lead authorship on analyses of calf mortality and birth interval. Results of the second workshop are presented in the "Report of the Second Workshop on the Estimation of Calf Mortality in North Pacific Humpback Whales", which was distributed to participants for review in June 1997.

During 1996, 8,321 additional humpback whale fluke photographs were entered into the computer-assisted matching system. The fluke database grew from 12,311 fluke photographs (as of late 1991) to 20,511 fluke photographs in October 1996. Progress in cross-matching photographs among research collections can be measured by looking at the number of photographs assigned a unique identification number. As of September 1996, there were 8,567 fluke photographs with a NMML ID (2,545 unique ID numbers) and 11,944 fluke photographs without a NMML ID. At this point, the exact number of individual whales cannot be determined because the database is still being cross-matched between areas and different research collections. Several interesting matches were discovered by the NMML in 1996. The first documented movement of a whale between California and Alaska was found. Also, a whale whose death was observed and documented in Hawaii in February 1996 was found to have been photographed on Alaska feeding grounds in two previous seasons. Summaries of whale movements between areas, number of photographs submitted from each area by year, and submissions of photographs by year and area from each research group are presented.

A new videodisc catalog was mastered in October 1996, again including photographs curated by the College of the Atlantic. In a period of 4 days in October, over 20,000 images were added to the new videodisc, including about 7,000 from the Atlantic, about 11,000 from the Pacific, and about 2,000 from western Australia. Production of 50 copies of the new videodisc was completed by mid-November, and NMML began using and distributing the new disc in late November.

Introduction

In 1985, the National Marine Mammal Laboratory (NMML) began development of a computer-assisted humpback whale (*Megaptera novaeangliae*) fluke photo-identification system in order to facilitate and enhance ongoing studies of humpback whales. Individual photographic collections curated by a number of researchers and research groups, when pooled throughout the North Pacific, would provide a better pool of information to study migratory patterns, distribution, birth rates and mortality rates. In April 1986, NMML hosted a workshop to demonstrate the prototype computer-assisted matching system and to develop a protocol for membership in the newly formed North Pacific Humpback Whale Working Group (Frady 1987).

Attendees included representatives from the Center for Whale Research, Center for Whale Studies, College of the Atlantic, J. Straley Investigations, Kewalo Basin Marine Mammal Laboratory, North Gulf Oceanic Society, Pacific Whale Foundation, Sea World Research Institute, Universidad Nacional Autonoma de Mexico, and West Coast Whale Research Foundation. The research goals for the centralized collection were to:

- provide a cost effective matching system
- assist NMML with data requirements pertaining to national and international management of humpback whale stocks
- increase scientific collaboration among research groups
- establish a permanent archive of photographs.

At the workshop, researchers provided suggestions for improving the prototype, which were incorporated in late 1986 by NMML, in collaboration with the College of the Atlantic. Kewalo Basin Marine Mammal Laboratory (KBMML) made the first contribution of photographs to the North Pacific collection (about 750 photos taken in Alaska and Hawaii) at the time of the 1986 workshop. By the end of 1988, the North Pacific collection had grown to over 5,000 fluke photographs, representing contributions from 16 research groups.

Life History Parameter Workshops

In order to use the North Pacific fluke photo collection to estimate various life history parameters and to increase collaboration among researchers, it was determined that a series of workshops should be planned to conduct studies on mortality, reproduction, and other topics.

In late 1988, NMML and KBMML began planning a workshop to estimate calf mortality in North Pacific humpback whales. With funding from NMFS, the Marine Mammal Commission and Minerals Management Service, NMML convened the first of a two-part workshop on the Estimation of Calf Mortality in North Pacific Humpback Whales from 20 to 23 November 1991. The purpose of the workshop was to use longitudinal photo-identification data to estimate calf mortality and the interval between successive calves (i.e., reproductive intervals).By November 1991, the date of the first workshop, there were 12,479 photographs in the system.

To estimate calf mortality, sightings of mothers with calves in Hawaii and with or without calves in Alaska were tallied. Contributing researchers and NMML were to analyze data on matches of females seen in Hawaii with a calf, and seen in Alaska that same year with or without a calf. Calf mortality would be assumed if the female was seen in Hawaii with a calf, then seen in Alaska without the calf later that year. At the end of September 1994, joint data analysis had found 68 female whales that had been seen in both Hawaii and Alaska or Canadian feeding areas. As of September 1996, with the much larger dataset available because of data entry this year, there were 90 females with sightings in both Hawaii and Alaska or Canada. The second Workshop on the Estimation of Calf Mortality in North Pacific Humpback Whales was held at NMML from 25 to 27 November 1996. Papers were presented on survey methodology, and workshop participants Gabriele and Straley agreed to take lead authorship on analyses of calf mortality and birth interval. Results of the second workshop are presented in the "Report of the Second Workshop on the Estimation of Calf Mortality in North Pacific Humpback Whales", which was distributed to participants for review in June 1997.

During developmental years of the project, funding was variable. At the beginning of 1992, work halted on the humpback whale project due to lack of funding and staff. In Spring 1994, work on summarizing and error-checking the database began, as well as incorporating matching data from the 1991 Calf Mortality Workshop (NMML 1995). A summary document, *List of Matches in the North Pacific Humpback Whale Fluke Photograph Collection, Master List, Release 1,* was distributed to all contributing researchers in September 1994 (NMML 1994).

In 1996, the project had directed funding for the first time. Because there was funding provided by the National Marine Fisheries MMPA/ESA Program, the program was staffed full-time for the first time ever. The backlog of photographs that had been accumulating since late 1991 was entered, as well as a number of new photographs that were submitted in 1996.

Number of Photographs in the Database

During 1996, 8,321 additional photographs were entered. The fluke database grew from 12,311 fluke photographs (as of late 1991) to 20,511 fluke photographs by October 1996.

Matches in the Database

NMML identification (ID) numbers are assigned when there are at least two photographs of a particular individual whale in the database. As of September 1996, there were 8,567 fluke photographs with a NMML ID (2,545 unique ID numbers) and 11,944 fluke photographs without a NMML ID (Table 1). At this point, the exact number of individual whales cannot be determined because the database has not yet been thoroughly cross-matched between areas and different research collections. Now that the backlog of photos has been entered, the primary focus in 1997 will be cross-matching the database and determining the exact number of individual whales in the collection. Table 2 shows the range of quality codes of the photographs in the system. The total number of photos presented in Table 2 does not add up to 20,511 because a small number of photographs were given ID numbers but not fully entered into the database with quality codes and fluke descriptions. Note that there are 1,454 photographs without a NMML ID that are poor in photo quality and recognizability. After extensive cross-matching has been conducted, we may find that most of these may not be matchable.

Several interesting matches were discovered in 1996. The first match of a whale observed to have moved between California and Alaska was documented. Also, a whale whose death was observed and documented in Hawaii in February 1996 was found to have a prior history. It had been photographed on Alaska feeding grounds in two previous seasons. A list of new matches found since 1994 (NMML 1994) is available for researchers upon request at this time in either hard-copy, DBF or Excel format, but will be not be mass produced and mailed until after further cross-matching is conducted.

Matches Between Areas

A summary of matches of whales that traveled from one area to another is presented in Table 3. This list is preliminary and should not be assumed to imply rates of exchange since the database has not been thoroughly cross-matched within and between areas. This information is presented at this stage to reconcile matches known in the database with matches known by contributing researchers. Appendix Tables 2-4 give detailed information about the matches listed in Table 3.

Distribution of Photographs by Year and Area

There are 19,801 photographs in the database that have date and location information. There are 997 photographs in the database that do not have a date associated; we have not yet received detailed information from the research group which submitted the photos. There are 19 photos with no area associated, most of which are opportunistically submitted shots.

Table 4 presents the distribution of photographs by year and area. There are a number of photographs archived at NMML but not yet entered that were taken in the late 1970s. NMML's priority has been to enter the newer photographs to enhance studies on reproduction and calf mortality. However, in studies of adult mortality, the earlier photographs would become useful to extend the sighting histories of a number of known whales.

The earliest photograph in the database at this time was taken by Dale Rice of the NMML in Mexico in 1966. There is no match yet to this photograph. The second earliest photographs were taken in 1976 in Alaska and Hawaii. The Alaska photograph was of whale NMML ID [229], taken by Mike Tillman (formerly of NMML), and it is a whale that has been photographed at least 16 times since the first sighting. The most recent photograph of [229] was taken in March 1996 off Molokai by David Mattila of the Center for Coastal Studies.

Submissions of photographs per year averaged about 1,648 (SD:155) from 1986 through 1994. The figures for 1995 and 1996 do not represent full samples because some research groups are still processing and analyzing those data.

Distribution of Photographs by Year and Research Group

A number of research groups have a long history of taking photographs, and some newer groups have started research projects in the past few years (Table 5). Table 6 presents a brief overview of photographs by research group by year. This table does not fully reflect the research histories of all the groups because a few research groups are a year or two behind in submitting photographs to NMML.

Distribution of Photographs by Research Group and Area

Some research groups have conducted research in several different areas. Table 7 gives an overview of where some of the major research groups have conducted studies. This table does not totally reflect the research histories of all the groups because some groups are still in the process of submitting photographs.

Videodisc Production

The computer matching system links a database containing whale data to a videodisc containing the fluke photograph images. There have been three prior editions of the videodisc produced, each including the North Pacific collection as well as North Atlantic and Antarctic photographs curated by the College of the Atlantic (COA). The last disc had been produced in October 1990. With 1996 funding, arrangements were made to master a new videodisc in October 1996, again including photographs curated by COA. In a period of 4 days in October, over 20,000 images were added to the new videodisc, including about 7,000 from the Atlantic, about 11,000 from the Pacific, and about 2,000 from western Australia. Production of 50 copies of the new videodisc was completed by mid-November, and NMML began using and distributing the new disc by late November.

Citations

Frady, T. 1987. Workshop on Humpback Whale Photo-identification, a summary of proceedings. Univ. Alaska Sea Grant Rep. 87-1. 12p.

National Marine Mammal Laboratory. 1994. List of matches in the North Pacific humpback whale fluke photograph collection. Mizroch, S. A. (ed.) Report submitted to North Pacific humpback whale researchers. Unpubl. rep. 107p.

National Marine Mammal Laboratory. 1995. Report of the workshop on the estimation of calf mortality in North Pacific humpback whales. Mizroch, S. A. (ed.) Report submitted to workshop participants. Unpubl. rep. 18p.

Table 1. Overall summary of photos in the computer database as of November 1996

Type of photograph	Number of photographs
Fluke photos	20,511
Dorsal fin photos	231
Miscellaneous photos (backs, lunge feeding, etc.)	58
Total number of photographs	20,800
Fluke photos without a NMML ID number (see text for explanation)	11,944
Fluke photos assigned a NMML ID number (see text for explanation)	8,567
Number of unique NMML ID numbers assigned to fluke photos	2,545

Table 2. Each photograph in the database is assigned two quality codes related to the quality of the image. Photo quality is based on focus, lighting, angle, and other factors that relate to the image. "Recognizability" is based on the amount and detail of the natural markings on the fluke itself. Note that the number of photos does not add up to 20,511 because a small number of flukes were matched before they were entered, and were not entered with all the matching codes into the database.

All fluke photos in the database, including matched and unmatched photos

	"Recognizability"			
Photo quality	Excellent	Good	Poor	**Total**
Excellent	2,524	324	35	2,883
Good	6,475	5,181	1,228	12,884
Poor	933	1,855	1,771	4,559
Total	9,932	7,360	3,034	20,326

Photos assigned a NMML ID number (i.e., at least one match)

	"Recognizability"			
Photo quality	Excellent	Good	Poor	**Total**
Excellent	1,549	145	11	1,705
Good	3,330	1,896	284	5,510
Poor	357	505	317	1,179
Total	5,236	2,546	612	8,394

Photos without a NMML ID number (no matches found yet)

	"Recognizability"			
Photo quality	Excellent	Good	Poor	**Total**
Excellent	975	179	24	1,178
Good	3,145	3,285	944	7,374
Poor	576	1,350	1,454	3,380
Total	4,696	4,814	2,422	11,932

Table 3a. Preliminary list of some of the matches between areas. These figures are just the minimum numbers known because the photos in the database have not yet been thoroughly cross-matched. Appendix Tables 2-4 present the data in more detail.

Numbers of individual whales seen in more than one area

	Alaska	California	Canada	Hawaii	Japan	Mexico	Oregon	Washington
Alaska				253		9		
California	1			1		29	1	1
Canada	3			18		3		1
Hawaii					1	7	1	
Mexico							2	

Table 3b. Individual whale ID numbers of whales seen in "unexpected" areas. NMML ID numbers are presented in brackets. For example, whale NMML ID [48] was seen in Alaska, Hawaii and Mexico. Whale NMML ID [190] was seen in California and Hawaii. See appendix tables for details of each match.

	Alaska	California	Canada	Hawaii	Japan	Mexico	Oregon	Washington
Alaska				[48] plus others (not presented-too preliminary)		[48] plus see appendix table 2		
California	[616]			[190]		[9613] plus see appendix table 3	[9613]	[9118]
Canada	[225] [12011] [12414]			see appendix table 4		[2044] [2244] [2021]		[2021]
Hawaii					[30077]	see appendix table 2	[16418]	
Mexico							[2112] [9613]	

Table 4. Number of photos in the database per year from each area. There are still a number of photographs from the late 1970s that are archived at NMML but were not yet entered as of November 1996.

Year	Alaska	California	Canada	Colombia	Hawaii	Japan	Mexico	Oregon	Washington	Total
1966							1			1
1976	1				1					2
1977			2		26					28
1978	1				64		41			106
1979	16				121		9			146
1980	154	3			497					654
1981	254				794					1,048
1982	194		1		311					506
1983	114	10	1		410		8			543
1984	366		1		201		10			578
1985	218	1	9		216		10			454
1986	522	96	4	1	866		108			1,597
1987	374	93	2		828	8	105			1,410
1988	247	111	16		1,362	25	89			1,850
1989	241	55	14		1,111	95	222			1,738
1990	144	115	13		973	122	247	23	1	1,638
1991	483	265	18		947	18	108			1,839
1992	877		28		594	15	177			1,691
1993	303		48		1,217	17	96			1,681
1994	572	241	1		415	37	82		13	1,361
1995	190				443	33	17			683
1996					245		2			247
Total	5,271	990	158	1	11,642	370	1,332	23	14	19,801

Table 5. Abbreviations and main contact people from the major contributing research groups. For full addresses, see Appendix Table 1.

Abbreviation	Research group	Contact People
CCS	Center for Coastal Studies	D. Mattila
CRC	Cascadia Research Collective	J. Calambokidis, G. Steiger
CWR	Center for Whale Research	K. Balcomb, D. Claridge
CWS	Center for Whale Studies	D. Glockner-Ferrari, M. Ferrari
GBNP	Glacier Bay National Park and Preserve	C. Gabriele
HWRF	Hawaii Whale Research Foundation	D. Salden
JSI	J. Straley Investigations	J. Straley
KBMML	Kewalo Basin Marine Mammal Laboratory	L. Herman, A. Craig
MLML	Moss Landing Marine Laboratories	S. Cerchio
NGOS	North Gulf Oceanic Society	O. von Ziegesar, C. Matkin
NMML	National Marine Mammal Laboratory	S. Mizroch
OEA	Okinawa Expo Aquarium	S. Uchida, N. Higashi
PBS-GE	Pacific Biological Station	G. Ellis
PWF	Pacific Whale Foundation	M. Osmond
UABCS	Univ. Autonoma de Baja Calif. Sur	J. Urban
UNAM	Univ. Nacional Autonoma de Mexico	M. Salinas, J. Jacobsen
WCWRF	West Coast Whale Research Foundation	J. Darling, E. Mathews, D. McSweeney, K. Mori

Table 6. Number of photos in the database contributed by each major research group, by year, as of November 1996. Funding sources for the research conducted were varied, including university contracts, private grants, and federal funding through NMFS or NOAA Sanctuaries programs.

Year	CCS	CRC	CRC/ CWR	CWR	CWS	GBNP	GBNP/ KBMML	HWRF	JSI	KBMML	MLML	NGOS	NGOS/ PWF	NMML	OEA	PBS-GE	PWF	UABCS	UNAM	WCWRF	Total
1966														1							1
1976														1			1				2
1977					1												1			12	14
1978					2							1					2			58	63
1979					4									1						127	132
1980					110				14	31		44		89						362	650
1981					102					296							68			581	1,047
1982					171					122							69			143	505
1983					179					180		2					33		8	126	528
1984					4					256		5					49		10	255	579
1985					41				46	1		8					128		9	188	421
1986			94		230	21	203		219	190		15					445		100	5	1,522
1987			93		227	33			56	398		12		3			321		102	9	1,254
1988	3	2	109	72	356	54			150	542		20	45				419			30	1,802
1989		55		52	398	64			103	432	172	87				1		3	163	109	1,639
1990	1	115		212	352	66			36	457	138	38		5		2		67		123	1,610
1991		265		14		56		201	293	426	320	66		61	18	4		108			1,832
1992						65		234	259	189	171	86		465	15	28		177			1,689
1993						51		411	141	498	308	47		64	17	48		96			1,681
1994		254				64		126	410	289		60		37	37	1		82			1,360
1995					110	62		214	76			45		1	33			16			557
1996	111				125			9													245
Total	115	691	296	350	2,412	536	203	1,195	1,803	4,307	1,109	534	45	728	120	84	1,536	549	392	2,128	19,133

Table 7. Number of photos in the database listed by research group from each area, as of November 1996.

Research Group	Alaska	California	Canada	Hawaii	Japan	Mexico	Oregon	Washington	Total
CCS				112		3			115
CRC		678						13	691
CRC/CWR		301							301
CWR			24			302	23	1	350
CWS				2,755					2,755
GBNP	537								537
GBNP/KBMML	203								203
HWRF				1,196					1,196
JSI	1,808								1,808
KBMML	566			3,828					4,394
MLML				1,109					1,109
NGOS	535			46					581
NGOS/PWF				45					45
NMML	761					2			763
OEA.					120				120
PBS-GE			84						84
PWF	32			1,512					1,544
UABCS						712			712
UNAM						621			621
WCWRF	612		34	1,236	250				2,132
Total	5,054	979	142	12,027	370	1,640	23	14	20,249

List of Appendix Tables

Appendix Table 1: Distribution list of this report

Mario A. Salinas Z.
Paloma Ladron de Guevara
Universidad Nacional Autonoma de Mexico
Apartado Postal 70-572
C.P. 04510, Mexico, D.F.
MEXICO

Scott Baker/ Anjanette Perry
School of Biological Sciences
University of Auckland
Auckland
NEW ZEALAND

Ken Balcomb/ Diane Claridge
Center for Whale Research
1359 Smuggler's Cove
Friday Harbor, WA 98250

Jay Barlow
Southwest Fisheries Center
P.O. Box 271
La Jolla, CA 92038

John Calambokidis/ Gretchen Steiger
Cascadia Research Collective
Waterstreet Bldg, Suite 201
218 ½ W. 4th Avenue
Olympia, WA 98501

Sal Cerchio
Musuem of Zoology, Birds
University of Michigan
Ann Arbor, MI 48109

Jim Darling
West Coast Whale Research Foundation
Box 384
Tofino, BC VOR 2Z0
CANADA

Doug DeMaster/ Rod Hobbs/ Janice Waite
National Marine Mammal Laboratory
7600 Sand Point Way NE
Seattle, WA 98115

Graeme Ellis
Pacific Biological Station
Nanaimo, BC
CANADA

Lilian Flores-Gonzalez
Fundacion Yubarta
Calle 36 Norte # 3N-66
Cali
COLOMBIA

Chris Gabriele
Glacier Bay National Park and Preserve
PO Box 140
Gustavus, AK 99826

Debbie Glockner-Ferrari/ Mark Ferrari
Center for Whale Studies
PO Box 1539
Lahaina, HI 96767

Lou Herman/ Alison Craig/ Rick Coleman
Kewalo Basin Marine Mammal Laboratory
1129 Ala Moana Blvd.
Honolulu, HI 96814

Jeff Jacobsen
PO Box 4492
Arcata, CA 95521

Mike Osmond
Paul Forestell
Pacific Whale Foundation
101 North Kihei Road, Suite 25
Kihei, Hawaii 96753

Elizabeth A. Mathews
West Coast Whale Research Foundation
PO Box 140
Gustavus, AK 99826

David Mattila
Center for Coastal Studies
PO Box 1036
Provincetown, MA 02657

Dan McSweeney
Box 139
Holualoa, HI 96725

Kyoichi Mori
Ogasawara Whale Watching Association
Nishi-machi
Chichi-jima, Ogasawara
Tokyo 100-21
JAPAN

Gene Nitta
NMFS - Pacific Area Office
2570 Dole Street
Honolulu, Hawaii 96822-2396

Dan Salden/ Jill Mickelsen
Hawaii Whale Research Foundation
PO Box 1296
Lahaina, HI 96767

Renata Santoro de Sousa Lima/ Marcia Engel
Instituto Baleia Jubarte
R. Cabralia 171, apt 401
Sao Lucas
Belo Horizonte, MG
Brazil

Fred Sharpe
Simon Fraser University
Dept of Biological Sciences
Burnaby BC V5A 1S6
CANADA

Greg Silber
Marine Mammal Commission
4340 East-West Highway, Room 905
Bethesda, MD 20914

Janice M. Straley
PO Box 273
Sitka, AK 99835

Senzo Uchida/ Noato Higashi
Okinawa Expo Aquarium
424 Ishikawa Motobu-cho
Okinawa 905-03
JAPAN

Jorge Urban
Universidad Autonoma de Baja California
Ap. Post. 219-B, Biologia Marina (Ciencias marinas)
C.P. 23000
La Paz, B.C.S.
MEXICO

Manami Yamaguchi
Ogasawara Marine Center
Byobudani Chichi-jima
Ogasawara, TOKYO 100-21
JAPAN

Judy Zeh
University of Washington
Department of Statistics - GN-22
Seattle, WA 98195

Olga von Ziegesar/ Craig Matkin
North Gulf Oceanic Society
PO Box 15244
Homer, AK 99603

Steve Zimmerman/ Linda Shaw
NMFS - Alaska Regional Office
PO Box 21668
Juneau, AK 99802

Appendix Table 2. List of whales seen in Mexico and other areas.

06-Oct-96

NMMLID	ACCESS	CONCODE1	CONCODE2	AREA	PHOTOAFF
48	48	0393	339	Hawaii	KBMML
	1568	6156	339	Hawaii	KBMML
	1569	6157	339	Hawaii	KBMML
	5243	16	29	Mexico	URI
	17028	SS87-16-11		Alaska	JSI
	39357	9126		Hawaii	KBMML
	39359	8749		Hawaii	KBMML
119	119	0757	567	Alaska	KBMML
	2539	5M89I047		Mexico	UABCS
	3793	AK81G	PWF793	Alaska	PWF
	6845	FS86-14-7		Alaska	JSI
	12285	285	81	Alaska	WCWRF
	15290	92PF7-46-F-30		Alaska	NMML
	17592	FS89-1-9A	567	Alaska	JSI
	37675	FS93-13(6)	567	Alaska	JSI
149	149	0896	544	Alaska	KBMML
	2245	5M87B014		Mexico	UNAM
	5182	81AL126	14	Alaska	KBMML
	6842	FS86-4-20A		Alaska	JSI
	6851	FS86-9-34		Alaska	JSI
	12085	85	98	Alaska	WCWRF
	15036			Alaska	IR
	15251	92PF8-49-O-2		Alaska	NMML
	36028	FS86-7-15	544	Alaska	GBNP/KBMML
155	155	0915	616	Alaska	KBMML
	2034	1M86B002	M34	Mexico	UNAM
	5153	81AL152	35	Alaska	KBMML
	6904	FS86-12-34		Alaska	JSI
	7028	SC86-4-14		Alaska	JSI
	12072	72	27	Alaska	WCWRF
	18035	GB50-13	616	Alaska	GBNP

NMMLID	ACCESS	CONCODE1	CONCODE2	AREA	PHOTOAFF
156	18463	GB90-57-32	616	Alaska	GBNP
	18521	GB91-31-1A	616	Alaska	GBNP
	18831	GB94-17-17	616	Alaska	GBNP
548	548	2458	418	Hawaii	KBMML
	615	2818	418	Hawaii	KBMML
	2008	2M86R003	M8	Mexico	UNAM
	2838	86 MRC 001		Mexico	UNAM
	3089	KA86046-15	PWF89	Hawaii	PWF
	8059	GF59	K48	Hawaii	CWS
	10146	146		Hawaii	WCWRF
	23130	T932	W83	Hawaii	CWS
	23687	MT41:17		Hawaii	CWS
	23804	MT103:21		Hawaii	CWS
	34463	SC-222	10:15	Hawaii	MLML
1024	1024	5617	000	Hawaii	KBMML
	2474	1M88R005		Mexico	UABCS
	2680	1M88R005	22:26	Mexico	UNAM
	2726	1M88R005	34:29	Mexico	UNAM
	4156	MU87511-6	1082	Hawaii	PWF
2009	2009	3M86R001	M9	Mexico	UNAM
	2908	90SJC14-21	5203	Mexico	UABCS
	4578	MK88083-32	1522	Hawaii	PWF
	22599	T599	W675	Hawaii	CWS
2021	2021	4M86R001	M21	Mexico	UNAM
	2821	86 MRS 021		Mexico	UNAM
	14138	91-15:27	39	Mexico	UNAM
	14575	SJC92-031	364	Mexico	UABCS
	16509	90PB20-11	14015	Canada	CWR
	20323	BC-23	J-21	Canada	WCWRF
	45253	JAC94-09/06	14015	Washington	CRC
2033	2033	1M86B001	M33	Mexico	UNAM
	5931		I13/16	California	CRC/CWR
	9733	JAC91-41/14	10002	California	CRC
	16346	90DEC30-10	10002	Mexico	CWR

NMMLID	ACCESS	CONCODE1	CONCODE2	AREA	PHOTOAFF
2033	45026	JRE94-15/21	10002	California	CRC
2035	2035	2M83B002	M-35	Mexico	UNAM
	2320	2M83B002	36	Mexico	UNAM
	9104	JAC8877/23	10204	California	CRC/CWR
	9807	JAC91-22/02	10204	California	CRC
2041	2041	4M86B004	M-41	Mexico	UNAM
	5949		G36/8	California	CRC/CWR
	9754	JAC91-14/30	10046	California	CRC
2044	2044	4M86B007	M-44	Mexico	UNAM
	16133	89JURHP07	18	Mexico	CWR
	20324	BC-24	I-14	Canada	WCWRF
2057	2057	5M86I025	M57	Mexico	UNAM
	9067	GS 12/4	10167	California	CRC/CWR
	9799	JAC91-36/17	10167	California	CRC
2058	2058	2M86I012	M58	Mexico	UNAM
	9024	DB 1/24	10124	California	CRC/CWR
	9781	JAC91-31/15	10124	California	CRC
	45071	JAC94-47/34	10124	California	CRC
2072	2072	4M86I007	M72	Mexico	UNAM
	9031	GS 22/9	10131	California	CRC/CWR
	9786	JAC91-56/07	10131	California	CRC
	45074	JAC94-72/31	10131	California	CRC
2103	2103	2M86I017	M103	Mexico	UNAM
	5899	KCB86TX57	D13/34	California	CRC/CWR
	9734	DWB91-08/08	10005	California	CRC
	45027	OSU94-01/24	10005	California	CRC
2105	2105	5M86I033	M105	Mexico	UNAM
	9050	GS 25/25	10150	California	CRC/CWR
	16066	88KCBHP10	16	Mexico	CWR
2109	2109	2M85I002	M109	Mexico	UNAM
	5903		H5/17	California	CRC/CWR
	5913		B22/16	California	CRC/CWR
	9739	JAC91-50/04	10014	California	CRC

NMMLID	ACCESS	CONCODE1	CONCODE2	AREA	PHOTOAFF
2112	2112	5M85I009	M112	Mexico	UNAM
	16420	90DEC56-06	12010	Oregon	CWR
2117	2117	1M85I002	M117	Mexico	UNAM
	9102	PB88-31/16	10202	California	CRC/CWR
	45092	JAC94-25/20	10202	California	CRC
2126	2126	5M84I011	M126	Mexico	UNAM
	5891		G4/37	California	CRC/CWR
	9756	TEC91-03/20	10048	California	CRC
2244	2244	5M87B013		Mexico	UNAM
	20326	BC-26		Canada	WCWRF
2417	2417	5M88R041		Mexico	UABCS
	39093	8468		Hawaii	KBMML
	39102	8475		Hawaii	KBMML
2419	2419	5M88R043		Mexico	UABCS
	12161	161	485	Alaska	WCWRF
	18849	GB94-24-22		Alaska	GBNP
	19409	X-54		Alaska	NGOS
	19740	X-54		Alaska	NGOS
2435	2435	4M88R031		Mexico	UABCS
	5188			Mexico	URI
	5189	33-33A	71	Mexico	URI
	5190	33-34	60	Mexico	URI
	5212	14	7A	Mexico	URI
	5225	10	26	Mexico	URI
	5226	10	27	Mexico	URI
	5248	002218		Alaska	WHOI
	5249	002220		Alaska	WHOI
	6708	Y-6		Alaska	NGOS
	19022	Y-6		Alaska	NGOS
2506	2506	1M88B009		Mexico	UABCS
	9301	DWB8834/14	11001	California	CRC/CWR
2508	2508	2M88B006		Mexico	UABCS
	9109	JCC88-8/8	10209	California	CRC/CWR
	9537	TK90-02/11	10209	California	CRC

NMMLID	ACCESS	CONCODE1	CONCODE2	AREA	PHOTOAFF
2508	16265	90AJL01-19	3063	Mexico	CWR
2532	2532	4M89I012		Mexico	UABCS
	9025	GS 12/3	10125	California	CRC/CWR
	9782	JLQ91-13/05	10125	California	CRC
	45072	GHS94-01/09	10125	California	CRC
2547	2547	5M89R057		Mexico	UABCS
	2548	5M89R057		Mexico	UABCS
	2679	5M89R057	22:20	Mexico	UNAM
	2745	5M89R057	40:17	Mexico	UNAM
	2749	5M89R057	41:13	Mexico	UNAM
	3602	MK86251	PWF602	Hawaii	PWF
2609	2609	3M89R048	3:4	Mexico	UNAM
	14024	230	3:4	Alaska	Biological Journeys
2662	2662	5M89R059	19:2	Mexico	UNAM
	2664	5M89R059	19:31	Mexico	UNAM
	2666	5M89R059	20:18	Mexico	UNAM
	34649	SC-360	04:9	Hawaii	MLML
2925	2925	90SCR14-02	5233	Mexico	UABCS
	38048	FS94-31-13		Alaska	JSI
	38065	FS94-33-1		Alaska	JSI
2962	2962	90SJC24-04	9020	Mexico	UABCS
	9219	DWB8810/31	9020	California	CRC/CWR
	9712	DWB91-06/24	9020	California	CRC
5016	5016	81AL22	20	Alaska	KBMML
	5083	81AL44	41A	Alaska	KBMML
	7227			Alaska	
	7228			Alaska	
	12047	47	25	Alaska	WCWRF
	14015	JJ#5	04:02	Alaska	Biological Journeys
	15402	33A		Alaska	
	16009	88KCBHP9	5	Mexico	CWR
	16010	88KCBHP9	3	Mexico	CWR
	16332	90PL06-18	5008	Mexico	CWR
	38146	FS94-40-6		Alaska	JSI

NMMLID	ACCESS	CONCODE1	CONCODE2	AREA	PHOTOAFF
5192	5192	23	53	Mexico	URI
	10116	116		Hawaii	WCWRF
5880	5880		G8B/30	California	CRC/CWR
	16350	90MS01-20	10020	Mexico	CWR
5898	5898	KCB86TX55	D11/28	California	CRC/CWR
	9443	BWD90-01/8	10023	California	CRC
	9744	JLQ91-08/15	10023	California	CRC
	16025	88KCBHP10	7	Mexico	CWR
5909	5909		D26/31	California	CRC/CWR
	9401	BWD89-1/13	10068	California	CRC
	9402	BWD89-1/9	10068	California	CRC
	9768	LTR91-03/04	10068	California	CRC
	16354	90KCB16-17	10068	Mexico	CWR
	45055	JRE94-11/15	10068	California	CRC
6720	6720	Y-10		Alaska	NGOS
	6770	18-6-5		Alaska	SWRI
	6774	57017	7	Alaska	SWRI
	6775	57018	31	Alaska	SWRI
	6777	57017	15	Alaska	SWRI
	6778	57017	20	Alaska	SWRI
	6780	57017	19	Alaska	SWRI
	16269	90DEC23-04	3067	Mexico	CWR
	19430	Y-10		Alaska	NGOS
	19662	Y-10		Alaska	NGOS
	19758	Y-10		Alaska	NGOS
	19834	Y-10		Alaska	NGOS
	19930	Y-10		Alaska	NGOS
	49018	Y-10		Alaska	NGOS
9066	9066	JCC 16/5	10166	California	CRC/CWR
	9533	KCBHP90-77/2	10166	California	CRC
	9798	JAC91-37/31	10166	California	CRC
	16365	90KCB03-04	10166	Mexico	CWR
	45087	JAC94-49/21A	10166	California	CRC
9113	9113	JAC8878/34	10213	California	CRC/CWR

NMMLID	ACCESS	CONCODE1	CONCODE2	AREA	PHOTOAFF
9113	9812	JAC91-37/17	10213	California	CRC
	16368	90DEC13-23	10213	Mexico	CWR
	45098	JAC94-27/34	10213	California	CRC
9228	9228	PB88-11/7	9029	California	CRC/CWR
	9717	JAC91-08/21	9029	California	CRC
	16342	90DEC04-22	9029	Mexico	CWR
	45014	KR94-13/34	9029	California	CRC
9247	9247	DWB8811/14	9004	California	CRC/CWR
	9501	JAC90-47/21	9004	California	CRC
	16007	88KCBHP1	26	Mexico	CWR
	16008	88KCBHP1	20	Mexico	CWR
9412	9412	JAC8929/17	10308	California	CRC
	9548	JAC90-33/10	10308	California	CRC
	16373	90CLJ01-13	T34	Mexico	CWR
9571	9571	TK90-D5/27	10415	California	CRC
	9845	JAC91-55/11	10415	California	CRC
	16029	88KCBHP15	3	Mexico	CWR
9586	9586	JAC90-41/32	10433	California	CRC
	16290	90DEC26-13	3088	Mexico	CWR
9613	9613	JAC90-48/26	12002	California	CRC
	9865	JAC91-47/03	12002	California	CRC
	14388	BCS-07	196	Mexico	UABCS
	14758	SJC93-041	196	Mexico	UABCS
	16237	90KCB10-26	3037	Mexico	CWR
	16411	90DEC57-25	12002	Oregon	CWR
9918	9918	RS91-N1C/24	10549	California	CRC
	16304	89DEC58-02	3102	Mexico	CWR
16305	16305	90PL01-39	3103	Mexico	CWR
	45172	JAC94-73/32	10692	California	CRC

Appendix Table 3. List of whales seen in California and other areas.

06-Oct-96

NMMLID	ACCESS	CONCODE1	CONCODE2	AREA	PHOTOAFF
190	9530	JAC90-39/24	10130	California	CRC
	9030	JAC 17/34	10130	California	CRC/CWR
	190	1084	152	Hawaii	KBMML
	3340	MK8230-25	PWF340	Hawaii	PWF
	10594	594		Hawaii	WCWRF
616	9510	NB90-D8/07	9510	California	CRC
	18829	GB94-15-3	566	Alaska	GBNP
	18609	GB92-10-20	566	Alaska	GBNP
	18935	GB95-18-3	566	Alaska	GBNP
	18317	GB8930-36A	566	Alaska	GBNP
	18356	GB89-8-11	566	Alaska	GBNP
	18422	GB90-33-18	566	Alaska	GBNP
	36094	FS86-19-33	566	Alaska	GBNP/KBMML
	15152		18A	Alaska	IR
	6818	FS86-13-5		Alaska	JSI
	37607	SS93-5(11)	566	Alaska	JSI
	5184	81AL131	9	Alaska	KBMML
	5185	81AL106	42A	Alaska	KBMML
	616	2834	566	Alaska	KBMML
	12143	143	156	Alaska	WCWRF
2033	45026	JRE94-15/21	10002	California	CRC
	9733	JAC91-41/14	10002	California	CRC
	5931		113/16	California	CRC/CWR
	16346	90DEC30-10	10002	Mexico	CWR
	2033	1M86B001	M33	Mexico	UNAM
2035	9807	JAC91-22/02	10204	California	CRC
	9104	JAC8877/23	10204	California	CRC/CWR
	2035	2M83B002	M-35	Mexico	UNAM
	2320	2M83B002	36	Mexico	UNAM
2041	9754	JAC91-14/30	10046	California	CRC
	5949		G36/8	California	CRC/CWR

NMMLID	ACCESS	CONCODE1	CONCODE2	AREA	PHOTOAFF
2041	2041	4M86B004	M-41	Mexico	UNAM
2057	9799	JAC91-36/17	10167	California	CRC
	9067	GS 12/4	10167	California	CRC/CWR
	2057	5M86I025	M57	Mexico	UNAM
2058	45071	JAC94-47/34	10124	California	CRC
	9781	JAC91-31/15	10124	California	CRC
	9024	DB 1/24	10124	California	CRC/CWR
	2058	2M86I012	M58	Mexico	UNAM
2072	9786	JAC91-56/07	10131	California	CRC
	45074	JAC94-72/31	10131	California	CRC
	9031	GS 22/9	10131	California	CRC/CWR
	2072	4M86I007	M72	Mexico	UNAM
2103	9734	DWB91-08/08	10005	California	CRC
	45027	OSU94-01/24	10005	California	CRC
	5899	KCB86TX57	D13/34	California	CRC/CWR
	2103	2M86I017	M103	Mexico	UNAM
2105	9050	GS 25/25	10150	California	CRC/CWR
	16066	88KCBHP10	16	Mexico	CWR
	2105	5M86I033	M105	Mexico	UNAM
2109	9739	JAC91-50/04	10014	California	CRC
	5913		B22/16	California	CRC/CWR
	5903		H5/17	California	CRC/CWR
	2109	2M85I002	M109	Mexico	UNAM
2117	45092	JAC94-25/20	10202	California	CRC
	9102	PB88-31/16	10202	California	CRC/CWR
	2117	1M85I002	M117	Mexico	UNAM
2126	9756	TEC91-03/20	10048	California	CRC
	5891		G4/37	California	CRC/CWR
	2126	5M84I011	M126	Mexico	UNAM
2506	9301	DWB8834/14	11001	California	CRC/CWR
	2506	1M88B009		Mexico	UABCS
2508	9537	TK90-02/11	10209	California	CRC
	9109	JCC88-8/8	10209	California	CRC/CWR

NMMLID	ACCESS	CONCODE1	CONCODE2	AREA	PHOTOAFF
2508	16265	90AJL01-19	3063	Mexico	CWR
	2508	2M88B006		Mexico	UABCS
2532	9782	JLQ91-13/05	10125	California	CRC
	45072	GHS94-01/09	10125	California	CRC
	9025	GS 12/3	10125	California	CRC/CWR
	2532	4M89I012		Mexico	UABCS
2962	9712	DWB91-06/24	9020	California	CRC
	9219	DWB8810/31	9020	California	CRC/CWR
	2962	90SJC24-04	9020	Mexico	UABCS
5880	5880		G8B/30	California	CRC/CWR
	16350	90MS01-20	10020	Mexico	CWR
5898	9744	JLQ91-08/15	10023	California	CRC
	9443	BWD90-01/8	10023	California	CRC
	5898	KCB86TX55	D11/28	California	CRC/CWR
	16025	88KCBHP10	7	Mexico	CWR
5909	9401	BWD89-1/13	10068	California	CRC
	45055	JRE94-11/15	10068	California	CRC
	9402	BWD89-1/9	10068	California	CRC
	9768	LTR91-03/04	10068	California	CRC
	5909		D26/31	California	CRC/CWR
	16354	90KCB16-17	10068	Mexico	CWR
9066	9798	JAC91-37/31	10166	California	CRC
	9533	KCBHP90-77/2	10166	California	CRC
	45087	JAC94-49/21A	10166	California	CRC
	9066	JCC 16/5	10166	California	CRC/CWR
	16365	90KCB03-04	10166	Mexico	CWR
9113	9812	JAC91-37/17	10213	California	CRC
	45098	JAC94-27/34	10213	California	CRC
	9113	JAC8878/34	10213	California	CRC/CWR
	16368	90DEC13-23	10213	Mexico	CWR
9118	9540	TK90-D5/28	10218	California	CRC
	45102	JAC94-06/24	10218	Washington	CRC
	9815	JAC91-35/07	10218	California	CRC

NMMLID	ACCESS	CONCODE1	CONCODE2	AREA	PHOTOAFF
9118	9118	JCC88-1/18	10218	California	CRC/CWR
9228	45014	KR94-13/34	9029	California	CRC
	9717	JAC91-08/21	9029	California	CRC
	9228	PB88-11/7	9029	California	CRC/CWR
	16342	90DEC04-22	9029	Mexico	CWR
9247	9501	JAC90-47/21	9004	California	CRC
	9247	DWB8811/14	9004	California	CRC/CWR
	16007	88KCBHP1	26	Mexico	CWR
	16008	88KCBHP1	20	Mexico	CWR
9412	9412	JAC8929/17	10308	California	CRC
	9548	JAC90-33/10	10308	California	CRC
	16373	90CLJ01-13	T34	Mexico	CWR
9571	9571	TK90-D5/27	10415	California	CRC
	9845	JAC91-55/11	10415	California	CRC
	16029	88KCBHP15	3	Mexico	CWR
9586	9586	JAC90-41/32	10433	California	CRC
	16290	90DEC26-13	3088	Mexico	CWR
9613	9613	JAC90-48/26	12002	California	CRC
	9865	JAC91-47/03	12002	California	CRC
	16411	90DEC57-25	12002	Oregon	CWR
	16237	90KCB10-26	3037	Mexico	CWR
	14758	SJC93-041	196	Mexico	UABCS
	14388	BCS-07	196	Mexico	UABCS
9918	9918	RS91-N1C/24	10549	California	CRC
	16304	89DEC58-02	3102	Mexico	CWR
16305	45172	JAC94-73/32	10692	California	CRC
	16305	90PL01-39	3103	Mexico	CWR

Appendix Table 4. List of whales seen in Canada and other areas.

06-Oct-96

NMMLID	ACCESS	CONCODE1	CONCODE2	AREA	PHOTOAFF
6	6	0052	479	Hawaii	KBMML
	879	4445	000	Hawaii	KBMML
	20304	BC-4	G-5	Canada	WCWRF
	20507	GE 4:14		Canada	PBS-GE
	22776	T776	W663	Hawaii	CWS
	29691	8351		Hawaii	KBMML
	39480	8574		Hawaii	KBMML
71	71	0489	48	Hawaii	KBMML
	1185	5862	48	Hawaii	KBMML
	1190	5853	48	Hawaii	KBMML
	1376	6363	48	Hawaii	KBMML
	1760	5980	48	Hawaii	KBMML
	1837	6030	48	Hawaii	KBMML
	3272	MK86194-6	PWF272	Hawaii	PWF
	5200	001100		Hawaii	SEA LIFE PARK
	10235	235		Hawaii	WCWRF
	20430	GE 1:4		Canada	PBS-GE
	28793	7085		Hawaii	KBMML
225	225	1253	211	Alaska	KBMML
	20414	GE 1:21A		Canada	PBS-GE
530	530	2427	18	Hawaii	KBMML
	8248	GF248		Hawaii	CWS
	10393	393		Hawaii	WCWRF
	20548	GE 1:19		Canada	PBS-GE
	34550	SC-288	03:28	Hawaii	MLML
	34551	SC-288	11:32	Hawaii	MLML
	34552	SC-288	11:30	Hawaii	MLML
	50169	95MC7-1-21	MC042	Hawaii	OMI
532	532	2435	419	Hawaii	KBMML
	20302	BC-2	A-13	Canada	WCWRF
	28295	6672	419	Hawaii	KBMML
1408	1314	6230	1029	Hawaii	KBMML
	1408	6245	1029	Hawaii	KBMML

NMMLID	ACCESS	CONCODE1	CONCODE2	AREA	PHOTOAFF
1408	1424	6288	1029	Hawaii	KBMML
	1582	6194	1029	Hawaii	KBMML
	20319	BC-19	D-11	Canada	WCWRF
1457	1457	6271	000	Hawaii	KBMML
	20423	GE 1:17A		Canada	PBS-GE
2021	2021	4M86R001	M21	Mexico	UNAM
	2821	86 MRS 021		Mexico	UNAM
	14138	91-15:27	39	Mexico	UNAM
	14575	SJC92-031	364	Mexico	UABCS
	16509	90PB20-11	14015	Canada	CWR
	20323	BC-23	J-21	Canada	WCWRF
	45253	JAC94-09/06	14015	Washington	CRC
2044	2044	4M86B007	M-44	Mexico	UNAM
	16133	89JURHP07	18	Mexico	CWR
	20324	BC-24	I-14	Canada	WCWRF
2244	2244	5M87B013		Mexico	UNAM
	20326	BC-26		Canada	WCWRF
4150	4150	MU87618-25	1073	Hawaii	PWF
	8183	GF183		Hawaii	CWS
	20525	GE 6:6A		Canada	PBS-GE
	22388	T388	W510	Hawaii	CWS
	23885	MT141:16		Hawaii	CWS
	23915	MT157:32		Hawaii	CWS
	39233	8623		Hawaii	KBMML
	39429	8483		Hawaii	KBMML
4223	4223	MU88142/27	1152	Hawaii	PWF
	20516	GE 3:15		Canada	PBS-GE
4632	4532	MK88036-27	1465	Hawaii	PWF
	20308	BC-8	C-34	Canada	WCWRF
	28066	6438	1101	Hawaii	KBMML
	28067	6438	1101x	Hawaii	KBMML
	28094	6466	1101	Hawaii	KBMML
	28250	6433	1101	Hawaii	KBMML
12011	12011	11	338	Alaska	WCWRF
	20411	GE 1:6		Canada	PBS-GE
12414	12414	414	704	Alaska	WCWRF

NMMLID	ACCESS	CONCODE1	CONCODE2	AREA	PHOTOAFF
12414	20429	GE 1:15		Canada	PBS-GE
20310	20310	BC-10	F-25	Canada	WCWRF
	20509	GE 3:3		Canada	PBS-GE
	28761	7053		Hawaii	KBMML
20327	20327	BC-27		Canada	WCWRF
	20330	BC-30		Canada	WCWRF
	28160	6531	1125	Hawaii	KBMML
20435	20435	GE 1:1A		Canada	PBS-GE
	23431	T1226	W220	Hawaii	CWS
	23432	T1227	W220	Hawaii	CWS
20511	20511	GE 2:21A		Canada	PBS-GE
	28660	6956		Hawaii	KBMML
20512	20512	GE 4:16		Canada	PBS-GE
	28824	7114		Hawaii	KBMML
	28849	7135		Hawaii	KBMML
	28853	7139		Hawaii	KBMML
20517	20517	GE 2:0A		Canada	PBS-GE
	23491	T1286	W318	Hawaii	CWS
20530	20530	GE 7:31		Canada	PBS-GE
	28876	7214		Hawaii	KBMML
	28880	7210		Hawaii	KBMML
20533	20533	GE 6:15A		Canada	PBS-GE
	50199	95MN2-3-18A	MN021	Hawaii	HWRF
	50200	95MN2-3-13A	MN021	Hawaii	HWRF
20547	20547	GE 1:1		Canada	PBS-GE
	50039	95MC4-1-17	MC010	Hawaii	OMI
	50040	95MC4-1-14	MC010	Hawaii	OMI
	50041	95MC4-1-18	MC010	Hawaii	OMI

ENDANGERED SPECIES ACT CLASSIFICATION CRITERIA FOR NORTH PACIFIC HUMPBACK WHALES

Leah R. Gerber and Douglas P. DeMaster

National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington, 98115

Abstract

The U.S. Endangered Species Act (ESA) requires that Recovery Plans include specific criteria that determine when species should be removed from the list of endangered and threatened wildlife. Preliminary quantitative criteria for ESA classification based on trends in abundance, abundance, distribution patterns, population viability analysis (PVA), and regulatory status were developed for the humpback whale *(Megaptera novaeangliae)* in the North Pacific. A workshop was convened at NMML 27-28 January 1997 to incorporate expert opinion into Endangered Species Act (ESA) classification criteria for the North Pacific population of humpback whales and other populations of large whales as possible. Consensus on a general approach for establishing classification criteria was reached, but identification of specific analytical methods and determination of management units require further research. The proposed criteria are sufficiently flexible to be applied to other large whale species, where adequate information are available to determine population structure, abundance, and trends in abundance. Data are not currently adequate to determine the status of the fin whale *(Balaenoptera physalus)*; however, it is possible to determine the status of the bowhead whale *(Balaena mysticetus)* in the North Pacific using the current approach.

Introduction

The U.S. Endangered Species Act of 1973 as amended defines categories for endangered and threatened species, but provides no quantitative criteria for deciding when a species should be listed. As a result, listing and recovery actions for marine mammals, as well as other species, are widely inconsistent. Of the 20 marine mammal species listed under the ESA, only 6 have recovery plans. Within these plans, criteria to delist or change status (i.e., from threatened to endangered or vice versa) vary greatly between species.

Eight of the eleven species of large cetaceans, including blue, fin, sei, humpback, right, bowhead, gray and sperm whales, were listed under the ESA in 1970 due to concern about overutilization and inadequate protective regulations. Since 1986, 11 large cetacean species have been protected from commercial whaling by the International Whaling Commission, and several species have large or increasing populations. At the same time that many large whale populations have apparently recovered, several small cetacean populations have declined. Because the original listing criteria are no longer valid and large whales have been completely protected for many years and are increasing in abundance, it has been proposed that some large whale species (or stocks) should be considered for removal from the list (Brownell et al. 1989, Braham 1991).

A classification scheme that is quantitative and objective is necessary to a) efficiently utilize scarce resources in classifying many stocks of large whales, and b) reliably delineate biologically-based levels of extinction risk for consistent ESA classification. Quantitative criteria which define extinction risks based on at least one of four or five criteria should be both applicable relative to the types of data typically available for population of large whales and robust to the uncertainty associated with such data. The initial approach of this study was to associate the two ESA categories of threat with the IUCN categories of threat to classify large whales pursuant to the ESA (IUCN 1994). The proposed classification was revised from the original IUCN list during a January 1997 workshop to accommodate species-specific life history parameters available for large whales. The system should be considered preliminary at this time pending a peer-review.

Methods

General Approach to Classification of Large Whales

Five basic types of data are used in developing classification criteria for each of the identified species: population viability analysis (PVA), abundance, trends in abundance, changes in distribution, and regulatory status. The classification criteria identified in Table 1 encompasses each of these factors; details of the criteria are described below.

Table 1. Preliminary classification criteria for North Pacific humpback whales.

Downlist from Endangered to Threatened	Downlist from Threatened to Delisted
1) All designated wintering and feeding areas will maintain a population size such that, over the next 10 years, there is a high probability that abundance will remain above a specified critical level (N_q), and	1) There is a high probability in the foreseeable future (20-30 years) that all designated wintering and feeding areas would not meet the criteria for being endangered (based on potential for decline), and
2) An international regime is in place and is effective in regulating human-related disturbance and mortality.	2) An international regime is in place and is effective in regulating human-related disturbance and mortality.

The language "designated" wintering and feeding areas is intended to imply that the criteria are robust to changes in available data about population structure. The critical level (N_q) was defined as the population size for which it is too late for management to prevent extinction, or the quasiextinction level. N_{end}, the threshold for endangered status, is the population level necessary to maintain a high probability of remaining above N_q for 10 years; N_{th}, the threshold for threatened status, is the population level necessary to maintain a high probability of remaining above N_{end} for a specified time (i.e., 20 or 30 years) (see Fig. 1).

$N_{end} = N_0$ such that Prob $(N_0 \ldots N_{10} > N_q) = 0.95$
$N_{th} = N_0$ such that Prob $(N_0 \ldots N_{25} > N_{end}) = 0.95$,

where;

N_q = critical level (e.g., 500)
N_0 = initial population size
N_t = population size at time t.

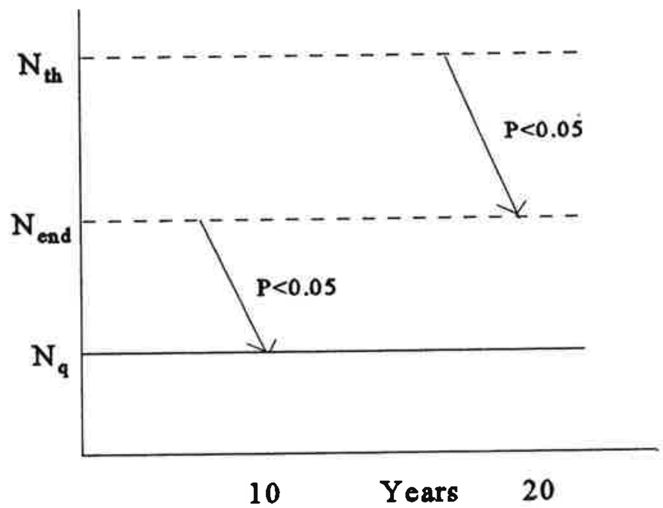

Figure 1. Schematic representation of classification criteria.

In Figure 1, the endangered status threshold is equivalent to a 0.05 probability of a population at N_{end} being at or below N_q after or during a 10-year period, and the threatened status threshold equivalent to a 0.05 probability of a population being at or below N_{end} in 20 or 30 years. In other words, if a population is above N_{end} or N_{th}, the probability that it remains above N_q or $N_{end,}$ respectively, is 0.95. Using this classification framework, N_q is fixed as a quasi-extinction level, while N_{end} and N_{th} are case-specific and depend upon available abundance and trend data.

The estimate of the projected abundance in year (t) becomes less certain as t increases. Therefore, the probability of a population declining below N_{end} and N_{th} increases with time. Similarly, relatively small initial population sizes (N_o) with large coefficient of variations (CVs) will have a high probability of declining below N_q. Conversely, large N_os with small CVs will have a low probability of declining below N_q. The effect of population size and associated CV on population trajectories will be investigated using computer simulations. This approach allows for incorporation of three types of uncertainty (described below) such that reclassification criteria become more conservative (precautionary) with increasing uncertainty. For each type of uncertainty, several methods for evaluating such uncertainty may be considered;

1) Underlying trend in population growth rate.
   a. Observed rate.
   b. Default rate (assumed based on empirical evidence from similar species or populations).
   c. Population assumed to be stable.

2) Variance in underlying trend in population growth rate.

a. Observed rates for other marine mammals (mainly pinnipeds).

b. Variability of life history parameters.

c. Default variability level.

3) Variance associated with abundance estimate.

a. Observed variance in abundance estimate.

b. Default variance in abundance estimate.

The criteria are intended to be applicable to a variety of types and levels of data quality and to encompass a precautionary approach. Further, the criteria are flexible in how uncertainty may be incorporated. For example, N_q may vary with the number and size of designated populations (which is dependent upon the tendency of whales to aggregate in feeding and wintering grounds, reflecting differences in genetic diversity); and the frequency and magnitude of stochasic events. Given these variables, it is clear that the determination of N_q should be case-specific. Further, the 95% probability specified in the criteria may be changed depending on what is considered an acceptable level of risk.

Results

Subsequent to the January workshop an analytic approach was developed to evaluate the status of North Pacific humpback whales in the context of the classification criteria described above:

(1) If $\lambda_{(.05)} < 1$ then $N_{end} = N_q * \lambda_{(.05)}^{-10}$
If $\lambda_{(.05)} \geq 1$ $N_{end} = N_q$
where $N_q = 650$.

As an initial approach, N_q was determined by the "minimum viable population size" method used by Ralls et al. (1983) for southern sea otters. The approach accounts for variance in sex ratio and percent immature, and assumes an effective population size of 500, resulting in an N_q estimate of 650.

Solving Equation 1 reveals the precautionary nature of the approach; as uncertainty in any life history parameter increases, the distribution around λ increases and the 5th percentile λ becomes smaller. Therefore, the threshold level for classification as endangered becomes larger (see Fig. 2).

A model was developed to evaluate the sensitivity of classification decisions to uncertainty in abundance, life history and critical threshold estimates (see Figs. 2 and 3). A life table developed by Barlow and Clapham (in press) and a range of survival rates estimated by Buckland (1990) were used to parameterize the demographic parameters of the model. First, incorporating all uncertainty from published estimates of survival rates (.52-.969) and using a fixed reproductive schedule as reported in Barlow and Clapham (in press), a range of scenarios encompassing different assumptions about starting population size (N_o) and quasiextinction thresholds (N_q) revealed the high probability of extinction over the next 10 years (see Fig. 3). This is because the resulting estimate of $\lambda_{(.05)}$ is substantially less than 1.0. However, while there are no estimates of survival rates for humpback whales in the North Pacific, it is likely that the true average survival rate is closer to .969 than .52, given that the population is probably increasing (Hill et al. 1997). Thus, results summarized in Figure 3 likely drastically overestimate the probability of extinction, but are nonetheless effective in displaying the sensitivity of the extinction distribution to assumptions about N_o and N_q.

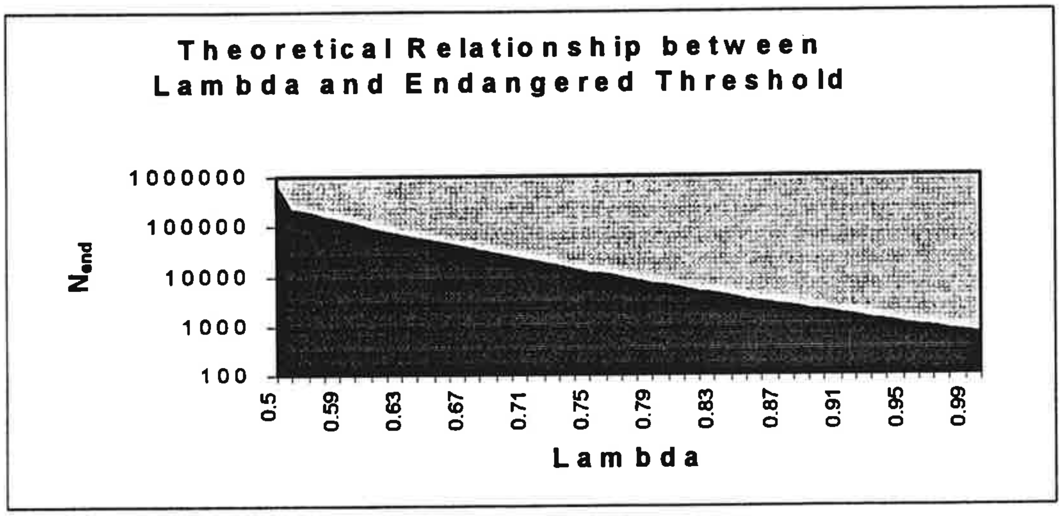

Figure 2. The Theoretical Relationship between Uncertainty in Parameters and N_{end}.

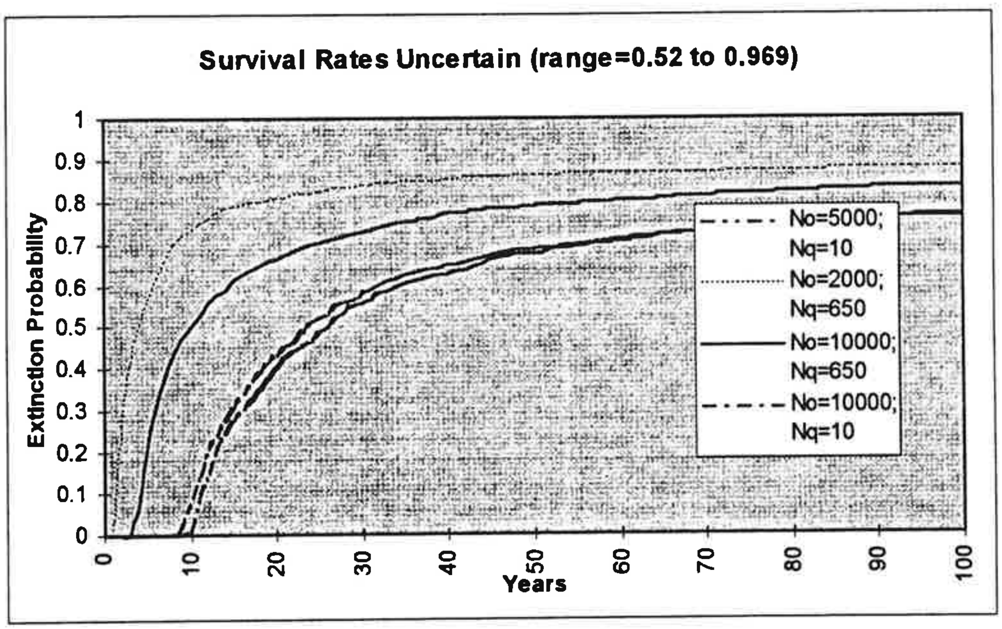

Figure 3. Effect of Uncertainty in N_o and N_q on Extinction Distribution for Humpback Whales.

A second set of simulations indicates the sensitivity of uncertainty in survival rates assuming N_o=2000, which corresponds to the minimum abundance estimate (N_{min}) for the Eastern and Central populations of humpback whales and N_q=650, corresponding to the "minimum viable population size" approach described above. Figure 4 illustrates that, as the range of uncertainty in survival rates (s.r.) is reduced, the probability of extinction in a 10-year time period decreases.

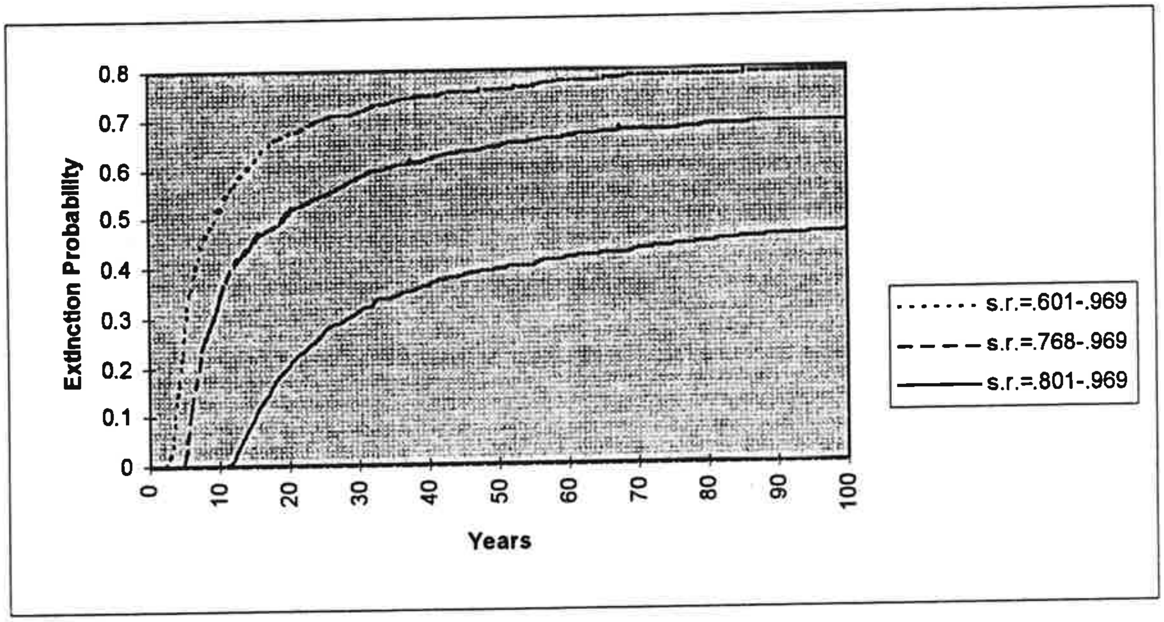

Figure 4. Cumulative Probability of Extinction; assumes N_o=2000 (N_{min}) and N_q=650 (MVP).

Another way to evaluate the specific effect of uncertainty on our estimate of N_{end}, is to consider the fifth percentile lambda value ($\lambda_{(.05)}$) resulting from 1,000 simulations corresponding to each range of uncertainty in survival rates. The results of solving equation 1 for each $\lambda_{(.05)}$ are presented in Figure 5; as noted earlier, where $\lambda_{(.05)} > 1$, N_{end} could be set at 650.

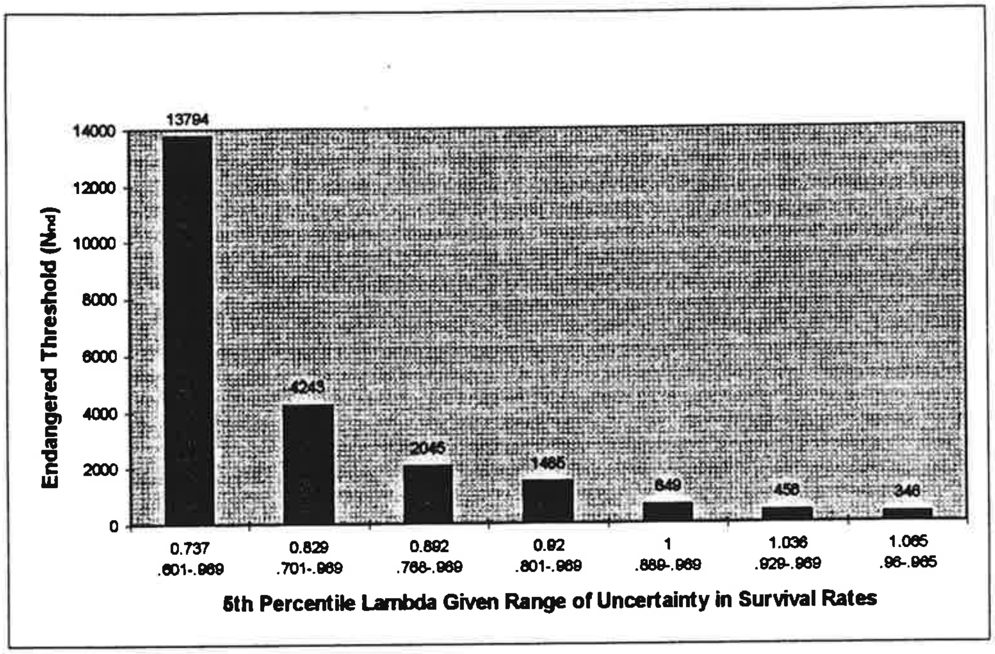

Figure 5. The Effect of Uncertainty in Survival Rates on N_{end}.

Discussion

The proposed classification scheme for humpback whales may be applied to other large whales, where adequate information are available. The sensitivity of ESA status to assumptions about population structure and parameterization of uncertainty may be investigated and incorporated into ESA classification of large whales. The key to using the approach described in this report is in selecting the most reasonable range for uncertainty in survival rates. An obvious extension that will be considered in future research on this topic is to explicitly incorporate uncertainty in life history parameters or λ using Bayesian techniques. It should also be noted that uncertainty in other life history parameters could be incorporated into the current model. Further research will evaluate the relationship between specific criteria and various input parameters [e.g., abundance, CV(abundance), trend, and CV(trend)] and will involve computer simulations, using population models appropriate for species with life histories similar to humpback whales.

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Appendix 1: Participants of Humpback Whale Classification Workshop (January 27-28 1997)

PARTICIPANT	AFFILIATION
Doug DeMaster	National Marine Mammal Laboratory (NMML)
Glenn VanBlaricom	University of Washington (UW)
Leah Gerber	UW
Barb Taylor	Southwest Fisheries Science Center (SWFSC)
Jay Barlow	SWFSC
Tim Gerrodette	SWFSC
Paul Wade	F/PR-NMFS
Sally Mizroch	NMML
Scott Mills	University of Montana
John Calambokidis	Cascadia Research
Phil Clapham	Smithsonian Institution/SWFSC
Jan Straley	University of Alaska
Jim Darling	West Coast Whale Research Foundation
Mike Payne	F/PR-NMFS
Chris Gabriele	Glacier Bay National Park and Preserve

SUMMARIES OF DATA COLLECTED FROM ICE-ASSOCIATED SEALS IN THE BERING, CHUKCHI, AND BEAUFORT SEAS, 1975-1991

Douglas P. DeMaster[1], David J. Rugh[1], Bete Jones[1], Lloyd F. Lowry[2], Kathryn J. Frost[2], and Gay Sheffield[2]

[1] National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way, NE
Seattle, Washington, 98115

[2] Alaska Department of Fish and Game
1300 College Road
Fairbanks, AK 99701

Abstract

In an effort to renew the study of the biology and ecology of ice-associated seals in the Bering, Chukchi, and Beaufort Seas, the National Marine Mammal Laboratory (NMML) contracted with the Alaska Department of Fish and Game (ADF&G) in 1995/96 to compile four species-specific computer databases. These include all morphological, reproductive, and archival specimen data from ringed, bearded, spotted, and ribbon seal specimens collected in the three seas from 1975 to 1991. Data were obtained from existing records compiled by Alaska Native hunters, Russian professional hunters, and researchers from ADF&G, NMML, and U.S. Fish and Wildlife Service during the 16-year period. The database does not represent the total number of the four species of seals harvested or collected during this period, as only seal records that contained morphological, reproductive, age, or archived specimen data were entered into the database. Data were recorded from a total of 5,547 seals: 62% (3,465) were ringed seals, 28% (1,531) were bearded seals, 9% (481) were spotted seals, and 1% (104) were ribbon seals. Most of the soft tissue samples are housed at NMML in Seattle, and most physical specimens are archived at the University of Alaska Museum in Fairbanks. The data collected during this study provide the background for future studies of ice-associated seals in the Bering, Chukchi, and Beaufort Seas. In addition, a small contract was let to the North Slope Borough (NSB) in FY96 for the purpose of providing support to local Native hunters who were willing to collect skin, teeth, reproductive or stomach samples from seals taken as part of the subsistence hunt.

Introduction

The Bering, Chukchi, and Beaufort Seas support eight species of pinnipeds, many of which are facing possible declines in their populations due to a number of environmental factors, including competition with commercial fisheries. Declines have been documented in Steller sea lions (*Eumetopias jubatus*) (Merrick et al. 1987), harbor seals (*Phoca vitulina*) in the Gulf of

Alaska (Pitcher 1990), and northern fur seals (*Callorhinus ursinus*) (NMFS 1993), while status and trends in the ice-associated seals are unknown. Ice-associated seals are heavily utilized by Native communities in coastal Alaska (see reviews in Lentfer 1988), but there are insufficient data to indicate trends in use (Rugh et al. 1997). Ice-associated seals include ringed seals (*Phoca hispida*), bearded seals (*Erignathus barbatus*), spotted seals (*Phoca largha*), and ribbon seals (*Phoca fasciata*).

Morphological and physiological studies of animals caught in subsistence hunts can provide insights into the health of the respective stocks. Data are available from approximately 1960-80 (Kelly 1988a,b,c and Quakenbush 1988), and include life history, condition indices, and food habits of all four species of ice-associated seals. In particular, there were many studies conducted during 1975-84 under the Outer Continental Shelf Environmental Assessment Program (OCSEAP). However, few data have been collected on ice-associated seals since the 1980s, partially due to a lack of monitoring of the subsistence take.

The purpose of this study was to synthesize the available data on the biology and ecology of the ice-associated seals in the Bering, Chukchi, and Beaufort Seas, as well as to promote the collection of new material. The outcomes of the study include: 1) a compilation of morphological, reproductive, and archived specimen data from ringed, bearded, spotted, and ribbon seals; 2) summary statistics and location of data available in each database; 3) a summary of archived specimens and their locations; and 4) an initiation of a sampling protocol for hunters to provide biological samples for subsequent studies.

Methods

Data records from seals collected in the Bering, Chukchi, and Beaufort Seas by Alaska Native hunters, Russian professional hunters, and researchers from ADF&G, NMML, and U.S. Fish and Wildlife Service between 1975 and 1991 were examined. Data were transferred electronically from previously archived text format computer files, or they were entered manually into four species-specific databases (using Foxpro 2.5b). Only seal records that contained morphological, reproductive, age, or archived specimen data were entered into each database. A master key to the database field definitions and data codes is presented in Sheffield et al. (1997: Appendix 1). Each record represents an individual animal and is cataloged with a specimen code, location code, and specimen number. Summary statistics of sample sizes, sex, reproductive, age, stomach, and morphological data, as well as archived physical specimens were calculated for each seal species by year and village.

Morphological, reproductive, and specimen data were considered available if at least 1 of the 15 morphological fields for a seal record contained data. Stomachs containing food data were totaled. The number of seals from which archived physical specimens are available at either the University of Alaska Fairbanks (UAF) museum or NMML were totaled and summarized by specimen type.

A final report from NSB is expected in the fall of 1997, regarding the collection of life history material by Alaska Native hunters under contract or an agreement with the NSB.

Results

Data were recorded from a total of 5,547 seals taken throughout the Bering, Chukchi, and Beaufort Seas from 1975 to 1991. Of these, 62% were ringed seals, 28% bearded seals, 9% spotted seals, and 1% ribbon seals. Most (94%) of the seal records were gathered between 1975 and 1979. Seals were collected from 10 villages and six research cruises in the Bering Sea, 7 villages and five research cruises in the Chukchi Sea, and 4 coastal locations and two research cruises in the Beaufort Sea. A summary report has been archived with the NMML library (Sheffield et al. 1997). In addition, a database for materials maintained within the NMML collection was also prepared (N. Angiel, pers. comm., EXCEL file: Arctic\iseal_db.xls). A copy of either is available upon request from the first author (D. DeMaster).

Physical specimens were taken from 3,856 seals as follows: teeth from 1,181; claws from 3,187; 189 os penises; 247 hyoids; 182 skulls; 13 skeletons; soft tissues from 98; and 5 embryos. The UAF museum contains all of the specimens of claws, os penises, hyoids, skeletons, and embryos, as well as over 99% of all teeth and skulls, and the NMML collection contains most of the soft tissue samples.

Ringed Seals

Data were obtained from 3,465 ringed seals collected in the Bering, Chukchi, and Beaufort Seas between 1975 and 1987. Villages with collections for five consecutive years included: Diomede, Gambell, Hooper Bay, Nome, and Savoonga in the Bering Sea, and Barrow and Shishmaref in the Chukchi Sea (see Sheffield et al. 1997: Table 1). Beaufort Sea data were collected from Prudhoe Bay for six consecutive years. Most (74%) of the Bering Sea seals were collected from the villages of Hooper Bay and Savoonga (Sheffield et al. 1997: Table 2 and Appendix 3). Diet data were collected from 1,017 stomachs. Most (72%) of the seals from the Chukchi Sea were collected from the village of Shishmaref.

Physical specimens were collected from 2,405 animals and included: teeth from 554; claws from 2,049; 98 os penises; 122 hyoids, 93 skulls; 2 skeletons; 5 embryos, and soft tissue from one (Sheffield et al. 1997: Table 3 and Appendix 4). All physical specimens are archived at UAF.

Bearded Seals

Data were obtained from 1,531 bearded seals collected in the Bering, Chukchi, and Beaufort Seas between 1975 and 1991. Villages where samples were collected for five consecutive years included: Diomede, Gambell, Hooper Bay, Nome, and Savoonga in the Bering Sea, and Shishmaref and Wainwright in the Chukchi Sea (Sheffield et al. 1997: Table 4). Half (50%) of all bearded seals from the Bering Sea were collected from the village of Hooper Bay. Most (76%) of the seals from the Chukchi were collected from the village of Shishmaref (Sheffield et al. 1997: Table 5 and Appendix 5). Diet data were collected from 368 stomachs. Bearded seal data were not available from 1982, 1984, and 1986-90.

Physical specimens were collected from 1,146 animals and included: teeth from 439; claws from 948; 28 os penises; 43 hyoids; 42 skulls; 3 skeletons, and soft tissues from 62 (Sheffield et al. 1997: Table 6 and Appendix 6). Physical specimens are archived at UAF and NMML.

Spotted Seals

Data were recorded from 481 spotted seals collected in the Bering, Chukchi, and Beaufort Seas between 1975 and 1991. Seal collections were available for four consecutive years at Shishmaref (Sheffield et al. 1997: Table 7). Most (73%) of the seals from the Chukchi Sea were collected from the village of Shishmaref (Sheffield et al. 1997: Table 8 and Appendix 7). Diet data were collected from 87 stomachs. Spotted seal data were not available during 1982-83 and 1986-90.

Physical specimens were collected from 238 animals and included: teeth from 167; claws from 143, 36 os penises; 46 hyoids; 24 skulls; 1 skeleton; and soft tissues from 23 seals (Sheffield et al. 1997: Table 9 and Appendix 8). Physical specimens are archived at UAF and NMML.

Ribbon seals

Data were recorded from 104 ribbon seals collected in the Bering and Chukchi Seas between 1976 and 1991. Most (96%) were collected in the Bering Sea. Samples were collected for two consecutive years from Gambell only (Sheffield et al. 1997: Table 10). Only 12% of all Bering Sea data were collected in villages, 88% were taken during five research cruises (Sheffield et al. 1997: Table 11 and Appendix 9). Diet data were collected from five stomachs. Seal data were not available during 1975, 1980-84, and 1986-90.

Physical specimens were collected from 67 animals and included: teeth from 21; claws from 47; 27 os penises; 36 hyoids; 23 skulls; 3 skeletons; and soft tissues from 62 (Sheffield et al. 1997: Table 12 and Appendix 10). Physical specimens are archived at UAF and NMML.

Discussion

The information regarding morphology, reproduction, age and sex classes of ice-associated seals was compiled into four databases that will provide the background for future studies of these species. As mentioned above, the soft tissue samples obtained from this study are archived at NMML while most of the physical specimens collected during this period are archived at the UAF museum. If funding is available, the 1-year project will be expanded to include the collection of additional biological specimen material. If adequate sample sizes are available, efforts will be undertaken to test various hypotheses regarding changes or trends in biological parameters since the 1970s (e.g., age of first birth, mean age, etc.).

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DISTRIBUTION AND ABUNDANCE OF RINGED SEALS IN NORTHERN ALASKA, MAY 1996

Douglas P. DeMaster[1], Janice M. Waite[1], Kathryn J. Frost[2], and Lloyd F. Lowry[2]

[1] National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington 98115

[2] Alaska Department of Fish and Game
1300 College Road
Fairbanks, Alaska 99701

Introduction

Ringed seals (*Phoca hispida*) are ice-associated pinnipeds with a circumpolar distribution north of roughly 55°N. These seals are well adapted to environments with seasonal and permanent sea ice, remaining near the ice most of the year, including pupping on the ice in late winter/early spring and rarely hauling out on land. These are the most abundant of the seals in Alaska, occurring sometimes as far south as Bristol Bay and near most of the coast of Alaska north to the Beaufort Sea. Their distribution and diet are a potential concern in that they may overlap with commercial fishery operations some of the year, and the seals undergo a regular harvest from subsistence hunters throughout much of their coastal range. To put this in perspective, the estimated annual subsistence take of ice seals is slightly larger than the total incidental mortality reported for all commercial fisheries in U.S. waters (as reported in Federal Register Vol. 62, No. 13, p. 3005-3009. 1997). Ringed seals are also impacted as the primary prey of polar bears, and may be affected by human activity, especially in shorefast ice habitats.

Understanding the population dynamics and stock structure of this species is severely limited by their wide distribution and difficult access over ice-covered seas. Efforts at monitoring rely on indices of population size, which have not yet been well established as to predictability and reliability (DeMaster 1995). Ringed seals in the Bering and Chukchi Seas are apparently migratory, but the extent of the migrations is unknown. Individual seals may occupy areas of at least 64 km^2 and may spend 12% to 30% of their time in lairs, with individual haul out bouts ranging from a few minutes to 20 hrs (Kelly 1988). Most previous aerial surveys have focused on seals hauled out during late April to June, at which time they are fairly obvious on the sea ice surface. Although, no reliable population estimate is currently available, this stock is not classified as a strategic stock (Small and DeMaster 1995).

In FY96 with funding from the Office of Protected Species, the National Marine Mammal Laboratory (NMML) participated in a study sponsored by the Minerals Management Service (MMS). The primary contract for the study was the Alaska Department of Fish and Game (ADF&G). The specific objectives of the study were to: 1) review and refine the previously established protocol for monitoring ringed seals by aerial surveys; 2) estimate relative abundance and density of molting ringed seals on fast ice in the Beaufort Sea during the spring/summer of 1996 and compare with data collected during 1985-1987; 3) correlate ringed seal densities on fast ice with environmental parameters; 4) determine abundance and density of molting ringed seals at and near industrial operations, and compare with otherwise comparable non-industrial areas; 5) review adequacy of ringed seal data collected by past industry site-specific monitoring programs, and make recommendations for protocols to be used in future industry studies; and 6) provide reports of findings that result from ringed seal monitoring to local residents and subsistence users. In this study, NMML personnel participated in the aerial survey portion and contributed to the analysis of the data. The primary data analysis performed by NMML staff was the comparison of strip transect data with simultaneously collected line transect data.

A final interim report was prepared for the MMS by Frost et al. (1997). Selected portions of that report are included herein.

Methodology

Aerial surveys were conducted in the central Beaufort Sea (Oliktok Point to Barter Island) during 28-30 May 1996 using previously established survey protocol. Twenty-three hundred and eighty-one kilometers of transects were covered. Surveys were flown at an altitude of 91 m (300 ft). During all surveys, two experienced observers counted seals following the previously developed ADF&G-MMS protocol (i.e., strip transect). The width of the surveyed strip was 0.41 km on each side of the plane. A third observer counted from a seat behind one of the primary observers and collected either line transect data or followed the established protocol. Line transect sightings were scored as being in one of five strips that were marked on the aircraft window with a grease pencil.

The survey aircraft was a twin-engine, high-wing Aero Commander (N7UP) chartered from Commander Northwest.

The line transect data were analyzed using the software package DISTANCE (Laake et al. 1994). For the strip transect data, mean density and its standard error were computed for each sector based on a standard ratio estimator. Variance was calculated using the jacknife procedure (Manly 1991). Density estimates were not corrected for sightability.

Results

A total of 1,596 seals in 822 groups were sighted. The average overall density of ringed seals was 0.82 seals/km^2. The average group size was 1.9 seals. Only 15% of the observed seals were counted in the fast ice, while 69% were counted in pack ice, and the remaining 16% were seen in ice that could not be classified. The lowest and highest total densities of ringed seals were 0.6 and 1.8 seals/km^2. The industrial prospect area, which is in the western portion of sector B3 (see Fig. 1; Frost et al. 1997), had lower seal densities than either the remaining part of B3 or sector B4.

Line transect analysis, using all of the recorded sightings where the bin in which the animal occurred was also recorded, resulted in a total of 237 observations of ringed seal groups over a distance of 1,259 km (i.e., 34 transects of effort searched). In addition, 84 sightings were reported, where distance from the trackline (i.e., bin) was not recorded. To avoid biasing the estimate of density, sightings where the bin number was not recorded were used in the line-transect analysis by randomly assigning a bin in proportion to their frequency (see Table 1). Where all 5 bins were used in the analysis, the best fit of the data to a sightings model was obtained using a Hazard Rate model. However, this model proved inadequate as the resulting Chi Square value from a Goodness of Fit test with 2 degrees of freedom was 17.74 ($p = 0.00014$). Furthermore, the model was not able to properly incorporate the relative lack of sightings in bins 1 and 2, as the resulting variance estimate was invalid (i.e., <0).

Table 1. Summary of line-transect data "bin" width during the May 1996 ringed seal survey.

Bin	Angle	Distance (m)	No. of Sightings	E (No. of Sightings)
1	45-66	40-91	4	23
2	34-45	91-134	23	20
3	21-34	134-235	54	46
4	9.5-21	235-538	147	139
5	<9.5	538-891	93	93

A second analysis was performed where the first two bins were pooled. This resulted in an improved fit of detection probability to perpendicular distance using a Hazard Rate model (Chi Square = 7.55, df= 1, p= 0.006); however, the model was still inadequate to explain the observed distribution of sightings by bin. Further pooling is not possible using DISTANCE because the degrees of freedom in the analysis drops to zero.

A third analysis was performed, where all of the sightings made in bin 1 were ignored (referred to as "left-truncation"). In this case, a uniform model with a second order polynomial adjustment provided the best fit (Chi Square = 0.16, df = 2, p= 0.92) to 317 observations of ringed seal groups. The estimate of density was 0.71 seals/km^2 (CV=0.13), where the effective strip width was 569 m (CV=0.05) and the average group size was 1.61 seals (CV=0.04). As cluster size was not independent of distance from the trackline, cluster size was estimated based on a regression of log(group size) versus g(x).

The average density using line transect methods was similar to the average density using strip transect methods (i.e., 0.71 seals/km^2 versus 0.82 seals/km^2). At this point, future analyses need to be undertaken to determine the precision of the two estimates per unit of sighting. That is, the CV of the density estimate using line transect methods was 0.13, based on 317 sightings, while the CV of the density estimate using strip transect methods was similar, but was based on over 800 sightings.

Conclusions

While the results presented in this report regarding the use of line-transect methodology to estimate the abundance of ringed seals should be considered preliminary, the following conclusions can be drawn. One, the current methodology, where the aircraft maintains an altitude of 91m and observers are instructed to search out to almost 900 m is inefficient when applied to line-transect analysis (i.e., the first bin of sightings data had to be discarded for the model to fit adequately). And two, a change in the methodology to allow line-transect analysis may confound a comparison of density estimates made in future years with existing density estimates (made using strip-transect methods), although the density estimates using strip transect methods and line transect methods were comparable in 1996.

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NORTHERN FUR SEAL STUDIES CONDUCTED ON THE PRIBILOF ISLANDS, 1996

Thomas R. Loughlin and Jason D. Baker

National Marine Mammal Laboratory,
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington, 98115

Introduction

In 1996, studies of northern fur seals (*Callorhinus ursinus*) were carried out on the Pribilof Islands, Alaska during July to November. Areas of research included monitoring of population size, subsistence harvest, offspring condition, prey selection, incidence of entanglement, pup mortality and disease, as well as special studies of female foraging, development of pups, and migration of pups. Research was conducted by National Marine Mammal Laboratory (NMML) staff, their contractors, and various collaborators including individuals and groups in the Aleut communities of St. Paul and St. George Islands, the Japanese National Research Institute of Far Seas Fisheries, University of California, and University of Alaska. Results of monitoring studies are published annually in the Alaska Fisheries Science Center's, NOAA, Technical Memorandum series, Fur Seal Investigations (FSI) report. Other studies will appear in peer-reviewed journals.

Population Assessment

Subsistence Harvest

A total of 1,588 sub-adult male seals were killed in the subsistence harvest by St. Paul Island residents in 1996. Three female fur seals were harvested accidentally on St. Paul Island. On St. George Island, 232 sub-adult male seals were taken in the subsistence harvest in 1996. Teeth were collected from approximately 20% of the harvested seals for age determination and as a record for studies of tooth microstructure. Serum and other tissues were collected from a sample of harvested seals and archived in the long-term fur seal tissue bank at NMML.

Living Adult Male Seals Counted

Total counts of adult male seals were conducted by section for each rookery on St. Paul Island from 11 to 17 July. A total of 5,643 harem and 9,239 idle adult male seals, also referred to as bulls, were counted on St. Paul Island. On St. George Island, a total of 1,248 harem and 790 idle adult male seals were counted from 10 to 16 July. There was an increase in the count of territorial males with females on St. Paul Island between 1995 and 1996 (9.5%), and the count of these males on St. George Island was slightly higher in 1996 than in 1995 (0.5 % more). The total for these males for the Pribilof Islands was therefore greater by about 7.7% in 1996.

Number of Pups Born on St. Paul Island in 1996

Since 1990, the number of fur seal pups has been estimated every other year, by conducting the shearing-sampling method on all rookeries (except on one very small declining rookery which is being protected from disturbance). In order to reduce disturbance while maintaining an acceptable level of precision, the number of fur seal pups was estimated on only six sample rookeries in August 1996. Sample rookeries were chosen at random with the additional requirement that there be two large, two medium and two small rookeries in the sample (following the protocol described in York and Towell (1996)). Counts of dead pups were made only on the same sample rookeries - not on all rookeries as in previous years. The techniques and resampling design used to calculate the production estimate on the sample rookeries were as in 1994, using paired observers (York and Kozloff 1987, Antonelis 1992, York and Towell 1996). The total number of pups alive at the time of sampling was estimated by multiplying the total number of breeding males from all rookeries by a jackknife ratio of pups to breeding males on the six sample rookeries (York and Kozloff 1987; York and Towell in press). The total number of dead pups was estimated from the mortality rate on the sampled rookeries. The total number of pups born was estimated by summing the estimates of live and dead pups. Variances of numbers of pups and mortality rates were estimated following York and Kozloff (1987) and York and Towell (in press); in addition, bootstrap variances of the parameters based on 2,000 replicates were also obtained.

From 8 to 13 August, 10,715 pups were marked by shearing. The number of pups sheared on each rookery was a random number between 10% and 15% of the 1994 pup production estimate. The random numbers between 10% and 15% were chosen in such a way that all persons participating in the census were blind to the actual percentage of the pups marked; this was done to minimize the potential bias caused by observers knowing that the total number of marked animals was a fixed percentage of the previous production estimate. Shear marks were allocated proportionally on each rookery by section according to the fraction of the rookery total for harem males counted in each section of the sampled rookery. The ratio of marked to unmarked pups was determined by at least three researchers (two of whom worked as a pair) on two occasions for each rookery from 14 to 22 August. Each researcher or pair of researchers obtained counts of marked and unmarked pups independently and in different areas to ensure that the entire rookery was well sampled. Each sampling day was considered an independent replicate from which the variance was computed for each rookery. Dead pups were counted on all sampled rookeries from 18 to 22 August.

Number of Pups Born on St. George Island in 1996

The number of pups born on St. George Island is estimated from a shearing-sampling study conducted on all rookeries. Because the number of pups born on St. George Island is relatively fewer, rookeries are not subsampled as on St. Paul Island. From 9 to 12 August, a total of 3,094 pups were shear-marked on St. George Island; the total number sheared on each rookery was a random number between 10%-15% of the total number estimated on the rookery in 1994, as on St. Paul Island. These marks were allocated proportionally within each rookery according to the fraction of harem bulls counted in 1996. The ratio of marked to unmarked pups on each rookery was determined by two researchers on two occasions: once from 14 to

19 August and again from 20 to 22 August. Counts of dead pups were made from 19 to 22 August 1996. The ratio of marked to unmarked pups and the estimate of the number alive was calculated similarly to the method described for St. George Island for 1994. Since the rookeries on St. George Island are much smaller than on St. Paul Island, one person is capable of sampling the entire rookery.

Counts of Dead Fur Seals Older Than Pups and Collection of Teeth

Tooth samples (usually canines) were collected from all dead fur seals other than pups whenever possible. The sample rookeries and adjacent beaches of St. Paul Island and all rookeries of St. George Island were surveyed for dead fur seals older than pups during August 1996. In 1996, tooth samples were collected from a total of 112 fur seals (20 males and 92 females) on St. Paul Island.

Pup Condition Study

Each year during late August, a sample of pups is rounded up at four trend sites on St. Paul Island and at each of six rookeries on St. George Island for determination of sex, mass and length. Pups are sampled as described in Antonelis (1992) and Robson et al. (1994). Pups were weighed to the nearest 0.2 kg using a spring scale; and length was determined to the nearest 1 cm. During 25-27 August 1996, a total of 1,181 pups (536 female, 645 male) were weighed and measured on St. Paul Island. A total of 750 pups (331 female, 419 male) were weighed and measured on St. George Island during 24-27 August 1996.

Prey Selection Monitoring

In order to monitor prey selection of northern fur seals foraging in the Bering Sea, scats are collected from rookeries and haul outs. During 18-27 August 1996, a total of 789 scats were collected on the Pribilof Islands. Hard parts of prey from these scats have been separated and most prey remains have been identified. This information will be combined and analyzed with a food habits database initiated in 1988.

Entanglement Studies

In 1996, in cooperation with the St. Paul and St. George Islands Tribal Councils and the Pribilof Islands Stewardship Program, NMML continued to study juvenile and adult male fur seal entanglement using a combination of research roundups and surveys during the subsistence harvest. The objective of this study, initiated in 1995, is to determine current trends in the rate of observed on-land entanglement of northern fur seals in marine debris on St. Paul and St. George Islands. This information is being collected in order to provide: 1) a continuing index of entanglement rates, 2) a comparison of entanglement rates on St. Paul and St. George Islands, 3) a means of indirectly assessing the relative amount of entangling debris within the habitat of the fur seal, and 4) an assessment of the proportion of debris types associated with different fisheries that are impacting fur seals.

In addition to the continuation of juvenile male entanglement studies, researchers continued to collect information on seasonal and annual (1991-95) rates of entanglement among adult female fur seals. As in previous years, researchers continued to capture and remove debris from entangled seals encountered during other research projects.

Male fur seals on hauling grounds located on St. George and St. Paul Islands were surveyed for entanglement in July and August 1996. Surveys were conducted in conjunction with the Aleut subsistence harvest and using non-harvest roundups following the methods described in Bengtson et al. (1988), Fowler and Ragen (1990) and Fowler et al. (1992). The harvest sampling protocol was adjusted to fit the logistical requirements of conducting the surveys during the subsistence harvest. Under each sampling regime, seals were prevented from escaping to the water and herded into groups by harvest or roundup crews. Seals were then released to sea in small groups or in a single file line allowing observers to count and examine seals for entangling debris or scars indicating previous entanglement. Separate counts were made by different observers of the total number of male seals (all age classes) and the number of juvenile male seals of the size and age (2-4 years old) historically taken in the commercial harvest (Bengtson et al. 1988, Fowler and Ragen 1990). Harvested seals were examined for entanglement and added to the final count. The count of adult seals was derived by subtracting the number of juveniles from the total count of all seals for a survey. Criteria for selection of juvenile males was based on overall size, pelage characteristics (color and thickness of mane, sagittal crest and chest patch) and vibrissae color and length (Scheffer 1962, C. W. Fowler pers. comm.).

When an entangled seal was sighted during release, the flow of seals to the water was stopped and the entangled seal was captured and the entangling debris removed. Information on the type of entangling debris, the extent of the wound, and the estimated age of the seal was recorded. Entangled seals judged to be of harvestable size were marked by lightly shearing marks into the pelage on the shoulders indicating the island of capture and type of survey. Marking enabled observers to resight previously entangled seals during subsequent surveys (Bengtson et al. 1988, Fowler and Ragen 1990). During the study period, juvenile male seals captured and disentangled during other research activities were also marked to indicate previous entanglement. Because some seals on haul outs are observed more than once (Fowler and Ragen 1990, Baker et al. 1995), entanglement rates of seals estimated from roundup samples (after 1985) are considered as samples taken with replacement. Samples taken during the commercial harvest (prior to 1985) in which both entangled and non-entangled seals were killed were obtained without replacement.

The overall rate of entanglement is estimated by the ratio of all (both initial and subsequent) entanglement sightings to the total of number of seals examined (Bengtson et al. 1988, Fowler and Ragen 1990). This estimate is subject to a slight upward bias due to the assumption that seals from which debris was removed would not have lost their debris independently (Scordino 1985).

Statistical analysis of entanglement data was performed using a general linear model assuming a binomial response. Factors were considered statistically significant if the deviance accounted for by that factor was greater than $\chi^2_{df,\,0.85}$ (where df is the number of levels of the factor -1). Factors examined in the analysis of the entanglement rate were: age (adult vs. juvenile), island (St. Paul vs. St. George), sample type (harvest vs. roundup sample) and the interaction between age, island and sample type in the rate of entanglement.

In 1996, island-wide surveys of entangled adult female fur seals were conducted on St. Paul Island using the techniques described by Kiyota and Fowler (1994). All rookeries were surveyed in conjunction with the counts of adult males from 12 to 17 July.

Twenty-three subsistence harvest surveys and 30 roundups were conducted on St. Paul Island (53 total) and 26 roundups and 9 harvest surveys (35 total) were conducted on St. George Island during July and early August of 1996. Observers sampled 38,311 seals (all age classes combined) on St. Paul Island and 10,763 seals on St. George Island. At total of 71 entangled juvenile and adult male seals were captured, examined and the debris was removed during harvest surveys and roundups (56 on St. Paul Island and 15 on St. George Island). Four entangled and seven scarred (evidence of previous entanglement) adult female fur seals were observed during female entanglement surveys on St. Paul Island. Details on entanglement rates and debris types will be presented in the upcoming 1996 Fur Seal Investigations report.

Pup Mortality and Disease

On St. Paul Island, pups which died at two sites were collected on a daily basis from 4 July to 9 August 1996. Remote weather stations at each site recorded data on temperature, humidity, rainfall, wind speed and wind velocity in order to relate early mortality to the influence of weather. A total of 172 dead pups were collected and necropsied. Tissues for toxicological and disease studies were collected from 35 of the pups. A detailed contract report prepared by Wildlife Pathology International regarding disease surveillance in 1996 is available at NMML.

On St. George Island, a special study of immunology in northern fur seal pups was conducted by University of Alaska, Fairbanks, with financial, logistical and field support from NMML. The goal of the study is to relate organochlorine (OC) levels with immune response. Mother/pup pairs were captured, a blood sample was taken from each and a milk sample was taken from the mother. These samples serve to establish OC levels and background immune system status. The pups were then injected with a benign tetanus antigen and released. After several weeks, pups were recaptured and a second blood sample was taken to determine the immune response capability of pups with varying OC loads.

A total of 44 mother/pup pairs were sampled according to the above protocol. A battery of tests related to OC levels, indicators of physiological response to OC, and several immunological response assays are currently being conducted. The bulk of laboratory analyses will be completed by July 1997.

Female Foraging

The second year of a 2-year study of the foraging behavior and energetics of lactating northern fur seal females was conducted on both St. Paul and St. George Islands. This was a collaborative study between NMML and University of California, Santa Cruz. The study design had a variety of treatments and controls, reflecting a number of questions being asked. These included:

- Do females from different islands, or from different breeding areas within islands, use distinctly different foraging areas?
- How does prey selection vary with foraging location and time and depth of diving?

- Are energy budgets (energy gained vs. expended) of females with differing foraging patterns distinct?
- How are females affected behaviorally and energetically by carrying telemetry instruments?
- Do milk fatty acids and fecal remains accurately represent prey selection of fur seals?
- Do female foraging patterns indicate that interactions with commercial fisheries are likely?

In 1996, a total of 46 females (31 on St. Paul, 15 on St. George) were tracked for one trip to sea with satellite transmitters. Dive recorders and radio transmitters were also attached to each female. Another set of 10 females on St. George Island was injected with doubly-labeled water (for measurement of energy intake and field metabolic rate), and instrumented with satellite transmitters, radio transmitters and dive recorders. An additional 20 females (10 on each island) were injected with doubly-labeled water and instrumented with a dive recorder and radio transmitter only. Finally, 5 females on St. George were instrumented with a dive recorder and radio transmitter, and 10 were instrumented with a radio transmitter only. No doubly-labeled water was administered to these latter two groups.

From all females captured during 1996, milk samples and fecal material (in the form of scat or enema) were collected for detailed prey analysis.

Development of Pups

In 1996, researchers from the University of California, Santa Cruz, with support from NMML, conducted the second year of a 2-year study on the energetics and physiological development of northern fur seal pups on St. Paul Island. In this study, milk intake and field metabolic rate of approximately 20 individual pups was measured throughout the lactation period. In addition, direct measurement of oxygen consumption (in air and in three water temperatures) was conducted on pups using a metabolic chamber during the pre-molt and post-molt stages of development. In this way, the development of thermoregulatory capabilities was characterized. In addition, growth rates, mothers' attendance, and development of blood and muscle chemistry were examined throughout the 4-month lactation period.

Simultaneously, NMML conducted complimentary studies on the ontogeny of swimming and diving behavior in pups. A total of 42 pups were fitted with a newly developed miniature "time wet recorder" (TWR), which records when pups enter and exit the sea. This study was designed to assess bias in population monitoring methods (such as the shearing-sampling census method, and pup mass and length monitoring) which assume that pups sampled on land are a random sample of the total pup population. Four pups were also instrumented with depth recorders, to characterize dive behavior and to determine whether pups may be foraging prior to migration. In addition, many of the pups with TWRs were also involved in the study of energetics and physiological development described above. As a result, energy/activity budgets can be constructed and the connection between physiology and behavior will be better elucidated.

Pup Migration

Each fall and winter, weaned pups migrate from the breeding islands and maintain a completely pelagic existence, usually for about 18 months. This is a critical period in the life history of northern fur seal pups when they learn to forage independently. Over half die during this first winter of life. In 1996, NMML began a 3-year study to determine the timing, direction, and foraging habits during migration. Six pups were instrumented with satellite transmitters, which transmit data on location and dive behavior. Of these, four pups were tracked for 2-4.5 months, providing the first detailed information on where pups go and what they do after disappearing from the Pribilof Islands.

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WINTER STELLER SEA LION PREY AND FORAGING STUDIES, (CRUISE SMMOCI-971) 7-23 MARCH 1997

Richard L. Merrick

National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington, 98115

Abstract

Scientists from the National Marine Fisheries Service, U.S. Fish and Wildlife Service, and Aleutians East Borough conducted a hydroacoustic-midwater trawl survey for Steller sea lion (*Eumetopias jubatus*) prey near three sea lion rookeries in Alaska waters during 7-23 March 1997. A total of 527 km of transects were completed as part of the basic surveys. Strong echo sign was rarely seen during the day, though distinct layers of zooplankton and fish were observed after 1-2 a.m. Preliminary biomass estimates suggest that midwater biomass was greatest at Ugamak Island and declined to the east (mean biomass densities over transects conducted during daylight were 42.3 kg/m^2, 9.8 kg/m^2, and 8.1 kg/m^2 at Ugamak, Atkins, and Marmot Islands, respectively). Thirteen midwater tows were conducted to identify selected echo sign. One long-line set was completed in rough bottom near each rookery to sample large fish and their prey. Oceanographic data were collected via a continuously operated thermosalinograph and conductivity-temperature-density (CTD) casts (47) conducted during the cruise. Sea surface temperature was typically around 3-4° C, with surface salinity in the range of 32-33‰. Thirty-seven hours of seabird and marine mammal sighting surveys were completed (25 hrs simultaneous with hydroacoustic transects). The most common seabird species observed were common and thick-billed murres, crested auklets, white winged scoters, and glaucous winged gulls; distinctly different from the species assemblage observed during summer surveys. A sea lion young-of-the-year was successfully tracked and it appeared to alternate between dive bouts of 10-15 minutes duration, and surface intervals of 5-10 minutes duration when away from the haul out. Given the long periods of diving and the presence of prey in the area (5 km away from the haul out), it is probably safe to conclude the animal was actively foraging.

Introduction

Scientists from the National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USF&WS), and Aleutians East Borough aboard the USF&WS vessel MV *Tĝlax̂* conducted a hydroacoustic-midwater trawl survey for Steller sea lion (*Eumetopias jubatus*) prey at three sites in Alaska waters during 7-23 March 1997 for a total of 17 sea days. The area of operations included the Ugamak, Atkins, and Marmot rookeries and waters surrounding these sites.

The principal objectives of the cruise were 1) to conduct hydroacoustic-midwater trawl surveys around Ugamak, Atkins, and Marmot Islands to compare results to surveys conducted during July 1996, and 2) to track instrumented juvenile sea lions and conduct hydroacoustic surveys at these animals foraging areas. Secondary objectives included collection of scats at one site, sighting surveys of marine mammals and seabirds during hydroacoustic surveys, and comparison tows of two different midwater nets.

Cruise Narrative

The cruise began at Dutch Harbor, Alaska, on 7 March 1997 with the scientific party boarding the MV *Tiĝlax̂* at that time (Tables 1 and 2). After departing that morning, the vessel proceeded to Ugamak Island, the first of the three sites to be visited for prey studies. While in transit, dense concentrations of common murres were observed north of Akun and Akutan Islands. Tows were conducted to determine the sign observed beneath the birds. The vessel arrived at Ugamak Island later that evening, with surveys beginning the morning of the eighth. Hydroacoustic surveys (161 km), 11 hrs of sighting surveys, 4 midwater and 3 neuston tows, 13 CTD casts, and 1 long-line set were performed over the next 3 days. Enormous numbers of crested auklets were observed to the north and east of the island, and sea lions were observed on Ugamak (beach A1) and Aiktak Islands. The vessel departed the site the evening of 10 March, and arrived at the Atkins Island study site the evening of 11 March.

Surveys were conducted at Atkins during 12-14 March, and included 136 km of hydroacoustic surveys, 7 hrs of sighting surveys, 2 midwater tows, 17 CTD casts, and 1 long-line set. Three of the transects were run during both daylight and nighttime periods to contrast prey densities by time of day. One transect was run an additional six times to test for differences in hydroacoustic techniques. No sea lions were seen at the traditional rookery site, but a small group of animals were at the north end of the island (J. Sease, NMFS, pers. comm, March 1997).

After the completion of the Atkins Island surveys on the morning of 14 March, we proceeded to Sand Point to drop off one of the scientific party (D. Lloyd). The vessel then proceeded on to Chowiet Island, conducting sighting surveys in transit, and arrived there on 15 March. As the vessel neared the island, large numbers of murres and occasional fin whales were encountered. No sea lions were found on the island. The vessel then conducted a hydroacoustic survey along a transect that was to be surveyed a few days later by the NOAA ship *Miller Freeman*. The vessel then proceeded on towards Chirikof Island and encountered additional fin whales while in transit. No sea lions were observed at Nagai Rocks, and some 200 sea lions were seen at the Chirikof Island rookery site. We then continued, through steadily worsening seas, towards Kodiak Island. We arrived in Chiniak Bay and subsequently, Kodiak City around noon on 16 March. While passing Long Island, a radio tagged (transmitter frequency 164.566) young-of-the-year sea lion was picked up on the NMFS VHF telemetry system installed on the ship. The large seas and high winds, however, forced us into town. We remained in Kodiak until the morning of 18 March. We then began a search for the animal, who apparently had gone to sea. After searching the area south to Gull Point and up to 16 nautical miles (nmi) offshore, we returned to Long Island to find the animal had returned. During the search, we observed 1 fin whale and 3 humpback whales to the southeast of Chiniak Bay. The vessel laid-to next to Long Island to await the animal's departure to sea. This occurred at 10:30 p.m. on 19 March. The animal was followed through the evening and morning of 20 March. After the animal hauled out at Long Island at 1:40 p.m. on 20 March, the vessel departed for Marmot Island. A group of killer whales were encountered during the transit to Marmot Island, and their very close approach provided an excellent photo opportunity.

Hydroacoustic surveys and trawling were conducted at Marmot Island on 21-22 March. Data were obtained from 196 km of hydroacoustic surveys, 6 hrs of sighting surveys, 4 midwater tows, 16 CTD casts, and 1 long-line set. Also, 5-6 gray whales were encountered during this period. After concluding these surveys on the morning of 23 March, the vessel turned for Homer, Alaska, and arrived there the same afternoon to end the cruise.

Methods

Hydroacoustic Surveys

Acoustic data were collected along a series of parallel transects within a 10 nmi radius of the three sites (Table 3., Figs. 1-3). Transect spacing was around 3 nmi. The vessel generally operated at 10 knots during this work. These data were collected using the vessel's BioSonics 102 system, with hull-mounted (4 m deep) 38 and 120 kHz transducers, operated in a multiplexing mode. All legs were surveyed once during daylight hours. The central three transects were also surveyed at night at Atkins and Marmot Islands. Settings for the BioSonics 102 unit were: receiver gain -6 dB (120 kHz) or -18 dB (38 kHz), TVG20, band width 5, pulse width 0.5, blanking distance 0.5 m, trigger interval 0.5 sec, and transmit power -3 dB. The system was run in multiplexing mode to obtain separate estimates of total biomass and fish biomass. All data were echo integrated in real time using BioSonics ESP software running on the ship's computer.

Data were analyzed post-survey using additional ESP software and EXCEL. Indices of total biomass were developed by averaging the biomass density (per m^2) obtained from each one minute segment of the survey across all segments for a site.

Midwater Trawls

Midwater trawls were conducted in support of the hydroacoustic surveys or other observations (e.g., feeding murres) to identify selected echo sign. These trawls were conducted using either a 6 m modified herring trawl or a neuston net towed for 15 minutes at 2-3 knots. A netsonde attached to the herring trawl's foot rope was used to determine fishing depth. Samples collected from these tows (typically euphausiids and 0-year aged fish) were counted, identified (as possible), and then frozen.

Long-line Sets

One long-line set was made offshore of each of the three sites. The long line consisted of one skate with 90-100 hooks baited with herring. Sets were made in water with hard bottom, approximately 50 m deep, and were allowed to soak around 3 hrs. All three sets were made at slack water in the early morning. Fish caught (halibut and cod, *Gadus macrocephalus*) were measured, weighed, and sexed. Stomachs were then removed and preserved in formalin for later identification at NMFS.

Seabird and Marine Mammal Sighting Surveys

During daylight hours of the hydroacoustic surveys members of the scientific party also conducted continuous sighting surveys of marine mammals and seabirds from the flying bridge (depending on visibility). Standard USF&WS seabird sighting protocols were observed. This involved two persons--one observer and one recorder. The 90° area from amidships to the bow (usually to port only) was observed continuously, with marine mammals and seabirds recorded by species and number.

Off-effort marine mammal sightings were recorded on the bridge using NMFS Form 10.

Oceanographic Data

A continuous thermosalinograph record was maintained throughout all hydroacoustic transects using the ship's Seabird Seacat SBE 21 thermosalinograph. A portable CTD (the ship's Seabird Seacat SBE-19 Profiler) was deployed at the beginning and end of each transect, and at the end of most tows and long-line sets to obtain salinity and temperature profiles for the entire water column.

Sea Lion Tracking

A male young-of-the-year Steller sea lion was captured at Long Island by NMFS personnel prior to entry of the vessel into the area, and a VHF transmitter (frequency 164.566) was glued to the pelage on the sea lion's head for tracking purposes. The vessel was fitted with an antenna array (four, four element Yagi antennae with one pointing in each of the four cardinal directions) attached to the ship's mast at the level of the crow's nest (around 15 m above the water level). Coaxial cabling from the antenna array ran into the ship's electronic room on the bridge, and was attached to a switch box. Each antenna could be isolated using toggle switches on the box; this allowed the direction of the animal with respect to the ship to be determined. A coaxial cable then fed the antenna signal into a VHF receiver with a small speaker for monitoring transmissions.

The ship anchored near the Long Island haul out while the animal was ashore. The animal was monitored continuously until it went to sea (as indicated by the receipt of intermittent rather than continuous signals). Once the animal was in the water, its position with respect to the ship was determined by isolating each antenna until the direction with the strongest signal was determined. The ship then moved in that direction to keep pace with the animal. If a direction could not be determined by isolating the antennae, a search pattern was followed which moved the ship in the direction of the strongest signal reception. For example, if the animal's location was unknown, the ship would move a half mile in the direction the animal had been moving and would then stop. If the signal was equal or greater in strength than the preceeding signal, the vessel would continue in that direction. If the signal was weaker, the vessel would return to the preceding position, and then move a half mile in another direction. After the animal returned to the haul out, its activities in the water were monitored from the ship until it returned to land.

A log was kept throughout the process which indicated the animal's bearing from the ship; number and strength of signals received in a transmission; and the ship's heading, speed, and location.

The ship's hydroacoustic system and continuous thermosalinograph were run throughout the tracking to obtain information on the prey and environmental conditions presented to the animal.

Results

Hydroacoustic Surveys

A total of 527 km of transects were run as part of the basic surveys conducted at the three sites--381 km during the day and 146 km at night (Table 3). Additional transects were run at Atkins Island (Six repetitions of transect AT7 to compare techniques; 38 km), Chowiet Island (to compare with the EK500 assessment of the same transect; 27 km), Long Island (for the tracking work), and Marmot Island (four repetitions of transect M3 to assess variance; 32 km).

Strong sign was rarely seen at any site during the day. However, at those sites where night time transects were run (Atkins, Long, and Marmot Islands) distinct layers of zooplankton and fish were observed after 1-2 a.m. For example, transect AT5 at Atkins Island showed no strong sign on the daylight transect. When the same transect was surveyed later in the evening, a strong scattering layer was observed at around 35 m. A tow on this layer showed it was composed of larval fish. This was underlaid by a layer of fish, which appeared to be walleye pollock (*Theragra chalcogramma*). An adult pollock was caught in the upper layer tow; a trawl on the lower layer was aborted due to malfunction of the net sounder.

Preliminary biomass estimates suggest that midwater biomass was greatest at Ugamak Island and declined to the east (Fig. 4). Mean density over daylight transects surveyed at Ugamak Island was 42.3 kg/m^2. Biomass density declined to 9.8 kg/m^2 at Atkins Island, and 8.1 kg/m^2 at Marmot Island.

This was a similar pattern compared to previous summer surveys. Compared to July 1996 surveys at the sites, the Ugamak Island biomass was somewhat higher in March than in July (37.5 kg/m^2), Atkins Island was somewhat lower (13.4 kg/m^2 in July), and Marmot Island was about the same (7.8 kg/m^2 in July).

Biomass estimates derived from the 120 kHz singly or in combination with the 38 kHz sounder (multiplexing) were compared at Atkins Island to ensure the two methods produced comparable results. Differences between the mean biomass of the three 120 kHz runs and the three multiplexed runs were not significant ($P = 0.246$).

Midwater Trawls

Nine midwater trawls were made with the herring trawl, one with an Issac-Kidd midwater trawl (IKMT), and three with a neuston net (Table 4). The midwater trawls found a variety of fish (including adult pollock), as well as euphausiids and a few jelly fish. The neuston tows were made to identify the sign being fed upon by murres and auklets in the eastern Aleutian Islands. Catches were generally composed of juvenile fishes, euphausiids, and copepods. Larval and juvenile fishes obtained were preserved for identification by NMFS.

A series of tows was made with the herring trawl and IKMT at Marmot Island to determine if the two nets sampled the same sign differently. The IKMT caught euphausiids and jellyfish. The herring trawl caught these taxa, but also caught juvenile (age-1 to age-3) walleye pollock at the same location and time. This suggests that tows made in previous years using the IKMT may not have adequately sampled the midwater sign observed.

Long-line Sets

Three long-line sets were made, one at each site (Table 4). The longline gear was deployed within 2 miles of each rookery on rough bottom. The gear caught Pacific halibut, Pacific cod, and sculpins. Stomachs were collected from 1 halibut and 8 (of 11 caught) Pacific cod at 40 m depth near Ugamak I., from 19 (of 20) cod at 36 m depth near Atkins I., and from 8 (of 8) halibut at 50 m depth near Marmot Island.

Oceanographic Data

47 CTD casts were made during the period (Table 5). These remain to be analyzed. Continuous sea surface temperature (SST) and salinity data were obtained from virtually all transects. SST was typically around 3-4° C, with surface salinity in the range of 32-33‰ (Table 3).

Marine Mammal and Seabird Sighting Surveys

Sighting surveys were run at all locations where hydroacoustics work was performed, and during transits between sites if weather permitted. Twenty-five hours of surveys (149, 10 min segments) were obtained simultaneous to the hydroacoustic surveys. An additional 12 hrs of surveys (71 segments) were obtained while the vessel was transiting between sites. The most common species observed were common and thick-billed murres, crested auklets, white winged scoters, and glaucous winged gulls. This was distinctly different from the species observed at the sites during summer--shearwaters, northern fulmars, tufted puffins, common murres, black-legged kittiwakes, and ancient murrelets. Sighting data is presently being entered for analyses of sea bird associations with hydroacoustic results.

Sighting records of marine mammals were maintained throughout the cruise (Table 6). Seven Dall's porpoise (*Phocoenoides dalli*) were observed, far lower than seen during the summer in the same areas. As in summer cruises, killer (*Orcinus orca*; 12 ± 1), fin (*Balaenoptera physalus;* 15), and humpback (*Megaptera novaeanglia*; 6 ± 1) whales were observed. Five to six gray whales (*Eschrichtius robustus*) were observed near Marmot Island. Killer whales were seen in sufficient numbers only once to attempt photography--in Marmot Bay on 20 March. As in previous work, significant concentrations of fin whales were observed in the southern Shelikof Strait area. Most of the humpback whales were observed in the area around Kodiak Island and the Barren Islands.

No pinnipeds were seen at sea. However, Steller sea lions were seen at the following sites: Aiktak, rocks north of Tigalda, Ugamak, Whaleback, Chirikof, Long, Marmot, and Sea Lion Rocks.

Sea Lion Tracking

The sea lion young-of-the-year was successfully tracked through one complete foraging trip from when it left the Long Island haul out (2242 on 19 March) to when it returned on land (1342 on 20 March). This was despite the failure of one VHF receiver, and the partial failure of the back-up unit (which would not work with the ATS direction finder). The vessel was able to maintain contact with the animal as it moved to the southwest of the island into Chiniak Bay. It was not possible, however, to resolve whether the animal foraged over the shelf or in the deeper waters of the Chiniak Gully. However, considerable fish sign was seen in waters less than 50 m deep over the Chiniak Gully, and it was possible that the animal could have been foraging on these fish. Use of the ATS direction finder would have resolved this problem.

The sea lion moved quickly from the haul out to sea, and returned to the haul out equally direct. However, when it returned, it spent over 5 hrs playing in the water next to the haul out. This would have resulted in numerous shallow dives being recorded and could account for the large number of shallow dives recorded for such animals. When the sea lion was away from the rookery, it appeared to alternate between dive bouts of 10-15 minutes duration, and surface intervals of 5-10 minutes duration. Given the long periods of diving and the presence of prey in the area the animal was diving (which was 5 km away from the haul out), it is probably safe to conclude the animal was actively foraging.

Conclusions

The cruise was a complete success, due in part to the excellent weather encountered during the period. Historical weather data had been consulted to determine the period, and the success of the cruise bears out the findings from this analysis that mid-March is the best weather window for this work.

The vessel and crew performed admirably, even in the storm encountered during the transit from Chowiet to Kodiak. Thus, the vessel should provide an excellent platform for future winter work.

The ship's BioSonics 102 system performed well throughout the cruise. This was the first time it had been used in a multiplexing mode, and the results of the 38 kHz integration have not been analyzed. However, a prelminary analysis of the 120 kHz biomass densities suggests that the results are comparable to running the 120 kHz system by itself. Results of the replicate transects at 120 kHz suggest that the variance in the biomass estimates may be greater than expected. This is a sampling problem, not one of the electronics, and will provide some insight into how survey results can be analyzed.

This was the first MV *Tiĝlax̂* cruise which used the modified herring trawl. In combination with the NetMind system, it provides a powerful tool for sampling midwater prey. Taxa from euphausiids and larval fish to adult pollock were obtained using the net, and as a result it appears to resolve the problem of sampling the midwater. Use of the IKMT to sample macrozooplankton and fish can probably be discontinued. The next net that needs to be obtained is a small bottom trawl net with roller or "rock-hopper" gear. The best sampling of midwater prey appears to be the late night or early morning, as midwater sign was rarely seen in trawlable concentrations during the day. Thus, future survey work will need to focus more on this night time period.

The long-line gear also appears to provide a simple, relatively fool proof sampling technique, and is now completely operational. However, the small samples obtained in the single skate (100 hook) sets are to small for statistical analysis. Thus, either additional skates or more sets will be necessary in the future.

The sighting surveys went well. Direct entry of data as collected into a ship board GIS (as planned by USF&WS) will improve the surveys' utility because it will speed data entry and analysis. A brief test of the communications link between an observer on the flying bridge and a recorder in the ship's electronics room, however, suggests that error rates could be significant (>10%). When the system becomes operational this summer, we will conduct additional tests to further explore the amount of error which occurs with the system.

Though the tracking work was successful, the inability to use the ATS direction finder made the process more difficult and inaccurate than was necessary. PTT data would have simplified our original location of the animal onshore (the failure of the original VHF receiver cost a day of searching for the animal). Communications with NMML to obtain data on the animal was a problem, as no one could be reached by phone at the office on several occasions. Plans of USF&WS to add satellite-based data or fax links to the ship would facilitate communications.

Table 1. Itinerary and activities for March 1997 cruise (SMMOCI-971).

Date	Location	Activity	Comments
05 March	Dutch Harbor	Scientific party arrive	
06 March	Dutch Harbor	Vessel arrives	
07 March	Dutch Harbor	Depart for Ugamak; tows off Akun	
08 March	Ugamak	Transects; sightings	
09 March	Ugamak	Transects	
10 March	Ugamak	Transects; sightings; long line	
11 March	At-sea	Transit to Atkins	
12 March	Atkins	Transects; sightings	Flat calm day
13 March	Atkins	Repetitive transects; complete regular transects	
14 March	Atkins to Sand Point	Long line; run to Sand Point	Denby Lloyd off
15 March	Chowiet	Run to Chowiet; Chirikof, and Kodiak; sightings	Storm in PM
16 March	At-sea to Kodiak	Run to Kodiak	Storm; Animal 566 on Long Island
17 March	Kodiak	In town	Don Dragoo off
18 March	Kodiak	Hunting for animal 566	
19 March	Long	Waiting for 566 to go to sea; tracking in late pm	
20 March	Long	Tracking until mid-day; depart for Marmot	

Table 1. (cont.).

Date	Location	Activity	Comments
21 March	Marmot	Transects; sightings	
22 March	Marmot	Long line; night transects	
23 March	Marmot to Homer	Night transects; trawling; transit	End cruise

Table 2. Scientific personnel involved with March 1997 cruise (SMMOCI-971).

Name	Sex/nationality	Position	Organization
R. Merrick	M/USA	Party Chief	NMFS
K. Chumbley	F/USA	Asst. Party Chief	NMFS
M. Strick	M/USA	Wildlife Biologist	NMFS
J. Thomason	M/USA	Wildlife Biologist	Contract employee
L. Baraff	F/USA	Wildlife Biologist	Contract employee
D. Lloyd	M/USA	Chief Resource Analyst	Aleutians East Borough
D. Dragoo	M/USA	Seabird biologist	USF&WS

Table 3. Prey survey transects during March 1997 cruise (SMMOCI-971).

		Begin					End					
Transect	Date	Time	Latitude	Longitude	SST	Salinity	Time	Latitude	Longitude	SST	Salinity	Trawl No.
UG-7	Mar 8	910	54 04	164 54	3.4		958	54 04	164 40	3.4		
UG-6	Mar 8	1041	54 07	164 34	1.7		1200	54 07	164 54	1.0		
UG-5	Mar 8	1254	54 10	165 03	1.2		1504	54 10	164 31	1.0		
UG-4 (E)	Mar 8	1523	54 13	164 30	1.1		1618	54 13	164 45	1.0		LL-1
UG-4(W)	Mar 9	1342	54 13	164 51	3.3		1445	54 13	165 14	3.5		
UG3	Mar 9	1549	54 16	165 03	3.4		1817	54 16	164 31	3.0	31.9	
UG1	Mar 10	1211	54 22	164 40	3.0	31.9	1308	54 22	164 54	3.0	31.9	N-3, MW-4
UG1	Mar 10	1515	54 22	164 54	3.0	31.9	1621	54 22	164 40	3.0	31.9	
UG2	Mar 10	1709	54 19	164 34	3.0	31.8	1820	54 19	165 00	3.2	32.0	
UG3	Mar 10	1907	54 16	165 03	3.3	32.1	2109	54 16	164 31	2.9	31.9	
AT7	Mar 12	919	55 00	159 27	2.6	31.8	945	55 00	159 34	2.7	31.8	
AT6W	Mar 12	1022	54 57	159 34	2.6	31.8	1043	54 57	159 28	2.7	31.8	
AT6E	Mar 12	1202	54 57	159 15	2.7	31.9	1238	54 57	159 05	2.9	31.8	
AT5	Mar 12	1322	55 00	159 02	3.2	31.9	1420	55 00	159 19	2.9	31.8	LL-2
AT4	Mar 12	1500	55 03	159 15	2.9	31.8	1544	55 03	159 02	3.2	31.9	
AT3	Mar 12	1625	55 06	159 02	3.5	32.0	1811	55 06	159 30	2.8	31.9	
AT2	Mar 12	1848	55 09	159 28	2.9	31.9	2008	55 09	159 05	3.5	32.0	
AT3N	Mar 12	2038	55 06	159 02	3.5	32.0	2216	55 06	159 30	2.8	31.8	MW-5
AT4N	Mar 12	2318	55 03	159 15	2.9	31.8	13	55 03	159 02	3.3	31.9	
AT5N	Mar 12	449	55 00	159 19	2.8	31.8	559	55 00	159 02	3.0	31.9	
AT7TEST	Mar 13	1247	55 00	159 27	2.6	31.8	1311	55 00	159 34	2.7	31.8	
AT7TEST	Mar 13	1312	55 00	159 34	2.7	31.8	1339	55 00	159 27	2.6	31.8	
AT7TEST	Mar 13	1340	55 00	159 27	2.6	31.8	1404	55 00	159 34	2.7	31.8	
AT7TEST	Mar 13	1406	55 00	159 34	2.7	31.8	1433	55 00	159 27	2.7	31.8	
AT7TEST	Mar 13	1434	55 00	159 27	2.7	31.8	1459	55 00	159 34	2.7	31.8	

Table 3. (cont.).

		Begin					End					
Transect	Date	Time	Latitude	Longitude	SST	Salinity	Time	Latitude	Longitude	SST	Salinity	Trawl No.
AT1	Mar 13	1951	55 12	159 15	3.3	32.0	2017	55 12	159 22	3.2	31.9	
MF4	Mar 15	1105	56 00	156 38	4.0	31.9	1253	55 55	156 06	4.1	32.2	
M1	Mar 20	1807	58 05	152 00	4.5	32.2	1844	58 11	152 00	4.1	32.3	
M2	Mar 21	930	58 04	151 55	4.5	32.3	1107	58 22	151 55	4.2	32.2	
M4	Mar 21	1140	58 23	151 50	4.2	32.5	1212	58 18	151 50	4.2	32.3	
M5	Mar 21	1258	58 22	151 45	4.7	32.7	1352	58 13	151 45	4.5	32.2	
M5	Mar 21	1425	58 13	151 45	4.5	32.3	1517	58 04	151 45	5.1	32.3	
M3	Mar 21	1607	58 03	151 50	5.0	32.2	1639	58 08	151 50	5.2	32.3	LL-3
M6	Mar 21	1726	58 05	151 40	5.4	32.3	1923	58 21	151 45	4.7	32.3	
M7	Mar 21	2015	58 17	151 35	4.8	32.3	2104	58 09	151 35	5.0	32.2	MW-7, MW-8
M3TEST	Mar 22	1818	58 08	151 50	4.7	32.2	1050	58 03	151 50	4.8	32.3	
M3TEST	Mar 22	1051	58 03	151 50	4.8	32.3	1121	58 08	151 50	4.8	32.2	
M3TEST	Mar 22	1122	58 08	151 50	4.8	32.2	1154	58 03	151 50	4.9	32.3	
M3TEST	Mar 22	1155	58 03	151 50	4.9	32.3	1225	58 08	151 50	5.0	32.2	
M2N	Mar 22	2043	58 22	151 55	4.5	32.3	2244	58 04	151 55	5.0	32.3	
M3N	Mar 22	2301	58 03	151 50	4.8	32.4	2330	58 08	151 50	4.7	32.2	
M5N	Mar 23	1	58 04	151 45	4.9	32.2	145	58 22	151 45	4.8	32.3	MW-9, MW-10

Table 4. Trawls and long line sets made during March 1997 cruise (SMMOCI-971). MW means midwater tow, LL means long-line, and NT means neuston (plankton) tow.

Trawl No.	Gear	Where	Date	Start Time	Latitude	Longitude	SST	Depth (m)	Dur (min)	Latitude	Longitude	CTD?	Contents
N-1	Neuston	Akun Head	Mar 7	1845	54 16.52	165 21.14	4.4	0	15	54 16.71	165 21.66	N	Juvenile fish
MW-1	Herring	Akun Head	Mar 7	1957	54 17.48	165 24.08	4.1	35	15	54 17.61	164 24.00	N	Empty
MW-2	Herring	Akun Head	Mar 7	2133	54 18.18	165 24.97	4.3		15			N	Euphausids
N-2	Neuston	Ugamak North	Mar 8	1708	54 14.13	164 46.86	0.9	0	15	54 14.13	164 47.42	N	Juvenile fish
MW-3	Herring	Ugamak North	Mar 8	1753	54 13.85	164 45.44	0.9	12	15	54 45.65	164 45.11	N	Euphausids
LL-1	LongLine	Ugamak Bay	Mar 9	610	54 11.13	164 47.60	3.2	50	145	54 11.67	164 47.67	Y	Cod (11), halibut (1), sculpins (16)
N-3	Neuston	Unimak Pass	Mar 10	1330	54 21.68	164 53.18	3.0	0	15	54 21.68	164 51.93	Y	Juvenile fish, copepods
MW-4	Herring	Unimka Pass	Mar 10	1422	54 20.58	164 48.71	3.0	15	16	54 20.60	164 50.59	Y	Jellyfish, euphausiids, juv. fish
MW-5	Herring	Atkins	Mar 13	222	55 06.1	159 07.5	2.8	12	15	55 06.1	159 09.0	Y	Adult pollock, larval fish, euphausiids
MW-6	Herring	Little Koniuji	Mar 14	106	54 59.9	159 33.5	2.9	35	15	55 59.9	159 35.2	Y	Euphausiids, larval fish
LL-2	LongLine	Atkins	Mar 14	530	55 0.4	159 19.2	3.0	36	170	55 00.7	159 19.6	Y	Cod (20), sculpins
MW-7	Herring	Marmot	Mar 22	432	58 11.7	151 34.7	4.8	75	15	58 10.5	151 34.9	N	Empty
MW-8	Herring	Marmot	Mar 22	534	58 11.7	151 34.7	4.7	80	15	58 10.5	151 34.3	N	Empty
LL3	LongLine	Marmot	Mar 22	700	58 9.3	151 49.5	4.3	43	135	58 09.5	151 48.9	Y	8 halibut
MW-9	Herring	Marmot	Mar 23	232	58 26.3	151 45.3	5.2	52	15	58 25.9	151 45.0	Y	Juvenile pollock (4), euphausiids, larval fish (1), jellies
MW-10	IKMT	Marmot	Mar 23	409	58 25.7	151 45.3	5.0	52	15	58 24.58	151 44.2	N	Euphausiids, jellies

Table 5. CTD casts made during March 1997 cruise (SMMOCI-971).

Cast	Where	Date	Time	Transect	Latitude	Longitude
0	Ugamak Bay	Mar 9	1033	na	54 12	164 49
1	Ugamak Bay	Mar 9	1035	na	54 12	164 39
2	Ugamak Pass	Mar 9	1336	UG-4	54 12	164 51
3	Ugamak Pass	Mar 9	1449	UG-4	54 13	165 04
4	Unimak Pass	Mar 9	1535	UG-3	54 16	165 03
5	Unimak Pass	Mar 9	1817	UG-3	54 16	164 31
6	Ugamak Bay	Mar 10	815	LL-1	54 12	164 48
7	Unimak Pass	Mar 10	1157	UG1	54 22	164 40
8	Unimak Pass	Mar 10	1315	UG1	54 22	164 54
9	Unimak Pass	Mar 10	1659	UG2	54 19	164 34
10	Unimak Pass	Mar 10	1823	UG2	54 19	165 00
11	Unimak Pass	Mar 10	1855	UG3	54 16	165 03
12	Unimak Pass	Mar 10	2109	UG3	54 16	164 31
13	Little Koniuji	Mar 12	906	AT7E	55 00	159 27
14	Little Koniuji	Mar 12	950	AT7W	55 00	159 34
15	Little Koniuji	Mar 12	1014	AT6W	54 57	159 34
16	Little Koniuji	Mar 12	1043	AT6W	54 57	159 28
17	Simeonof	Mar 12	1156	AT6E	54 57	159 15
18	Simeonof	Mar 12	1242	AT6E	54 57	159 05
19	Atkins	Mar 12	1322	AT5E	55 00	159 02
20	Atkins	Mar 12	1422	AT5W	55 00	159 19
21	Atkins	Mar 12	1500	AT4W	55 03	159 19
22	Atkins	Mar 12	1545	AT4E	55 03	159 02
23	Atkins	Mar 12	1615	AT3E	55 06	159 02
24	Atkins	Mar 12	1815	AT3W	55 06	159 30
25	Atkins	Mar 12	1840	AT2W	55 09	159 28
26	Atkins	Mar 12	2010	AT2E	55 09	159 05
27	Atkins	Mar 13	1941	AT1E	55 12	159 15
28	Atkins	Mar 13	2019	AT1W	55 12	159 22
29	Atkins	Mar 14	829	LL-2	55 00	159 20
30	Shelikof Gully	Mar 15	1100	MF4W	56 0.3	156 36.7
31	Shelikof Gully	Mar 15	1253	MF4E	55 54.9	156 5.8
32	Marmot	Mar 20	1756	M1S	58 05	152 00
33	Marmot	Mar 20	1844	M1N	58 11	152 00
34	Marmot	Mar 21	915	M2S	58 04	151 55
35	Marmot	Mar 21	1113	M2N	58 22	151 55
36	Marmot	Mar 21	1135	M4N	58 23	151 50
37	Marmot	Mar 21	1214	M4S	58 18	151 50
38	Marmot	Mar 21	1249	M5N	58 22	151 45

Table 5. (cont.).

Cast	Where	Date	Time	Transect	Latitude	Longitude
39	Marmot	Mar 21	1520	M5S	58 04	151 45
40	Marmot	Mar 21	1551	M3S	58 03	151 50
41	Marmot	Mar 21	1683	M3N	58 08	152 50
42	Marmot	Mar 21	1726	M6S	58 05	151 40
43	Marmot	Mar 21	1925	M6N	58 21	151 40
44	Marmot	Mar 21	2005	M7N		
45	Marmot	Mar 21	2005	M7N	58 17	151 35
46	Marmot	Mar 21	2104	M7S	58 09	151 35
47	Marmot	Mar 22	949	LL-3	58 09.5	151 48.9
48	Marmot	Mar 23	316	MW-9	58 25.7	151 45.9

Table 6. Marine mammal sightings during March 1997 cruise (SMMOCI-971).

Common name	*Scientific name*	Date	Time	Latitude	Longitude	#
Dall's porpoise	*Phocoenoides dalli*	7 Mar	2:07 pm	54 04.9	166 18.9	3
Killer whale	*Orcinus orca*	8 Mar	8:13 am	54 09.9	164 54.6	4
Dall's porpoise	*Phocoenoides dalli*	13 Mar	6:40 pm	55 12.0	159 15.0	4
Fin whale	*Balaenoptera physalus*	14 Mar	1:30 pm	55 14.4	160 17.2	1
Fin whale	*Balaenoptera physalus*	15 Mar	8:44 am	56 00.9	156 55.3	1
Fin whale	*Balaenoptera physalus*	15 Mar	10:17 am	56 02.1	156 37.0	1
Fin whale	*Balaenoptera physalus*	15 Mar	10:46 am	56 00.1	156 36.7	2
Fin whale	*Balaenoptera physalus*	15 Mar	1:20 pm	55 53.0	156 02.6	6
Fin whale	*Balaenoptera physalus*	15 Mar	1:35 pm	55 51.7	155 59.1	1
Fin whale	*Balaenoptera physalus*	15 Mar	1:35 pm	55 51.3	155 57.9	2
Humpback whale	*Megaptera novaeangliae*	18 Mar	11:00 am	57 41.9	151 48.2	1
Fin whale	*Balaenoptera physalus*	18 Mar	11:20 am	57 40.6	151 50.5	1
Humpback whale	*Megaptera novaeangliae*	18 Mar	2:30 pm	57 20.4	152 22.0	2
Killer whale	*Orcinus orca*	20 Mar	8:45 am	57 46.5	152 13.3	2±1
Humpback whale	*Megaptera novaeangliae*	20 Mar	10:30 am	57 46.5	152 13.3	3±1
Killer whale	*Orcinus orca*	20 Mar	3:02 pm	57 50.5	152 7.2	6
Grey whale	*Eschrichtius robustus*	21 Mar	1:57 pm	58 12.6	151 46.2	4±1
Grey whale	*Eschrichtius robustus*	21 Mar	2:45 pm	58 08.4	151 45.2	1

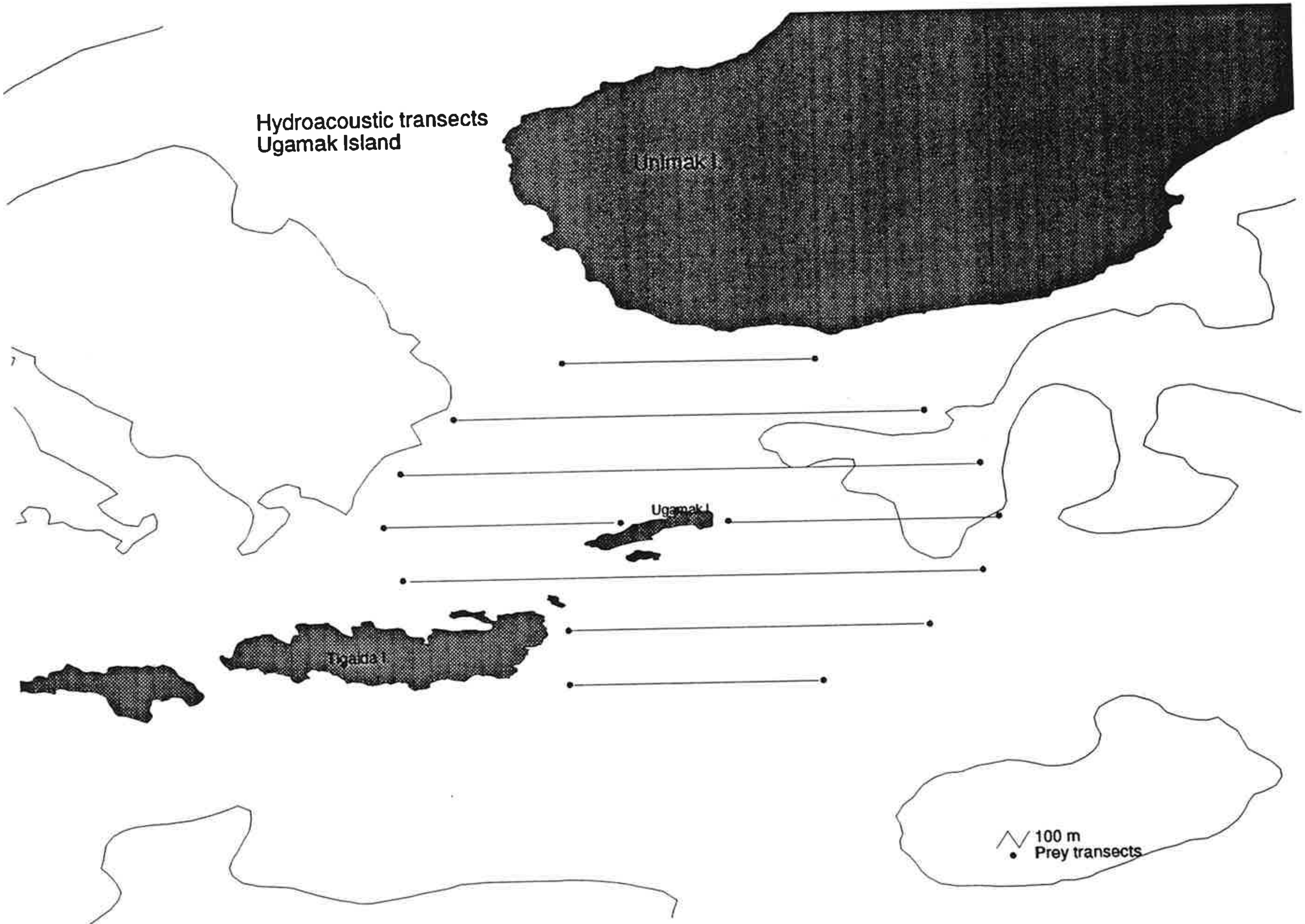

Figure 1. Hydroacoustic transects near Ugamak Island, Alaska.

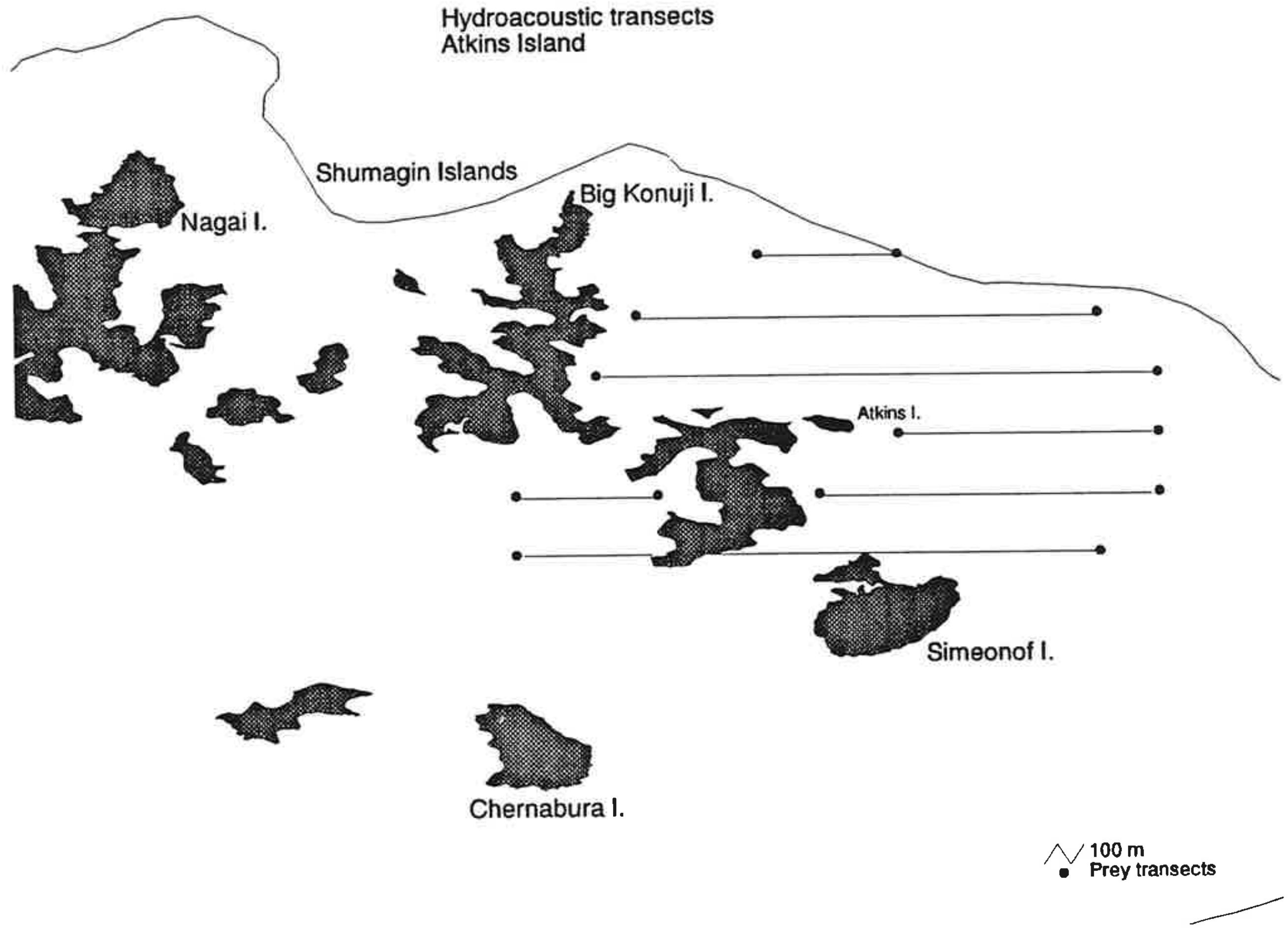

Figure 2. Hydroacoustic transects near Atkins Island, Alaska.

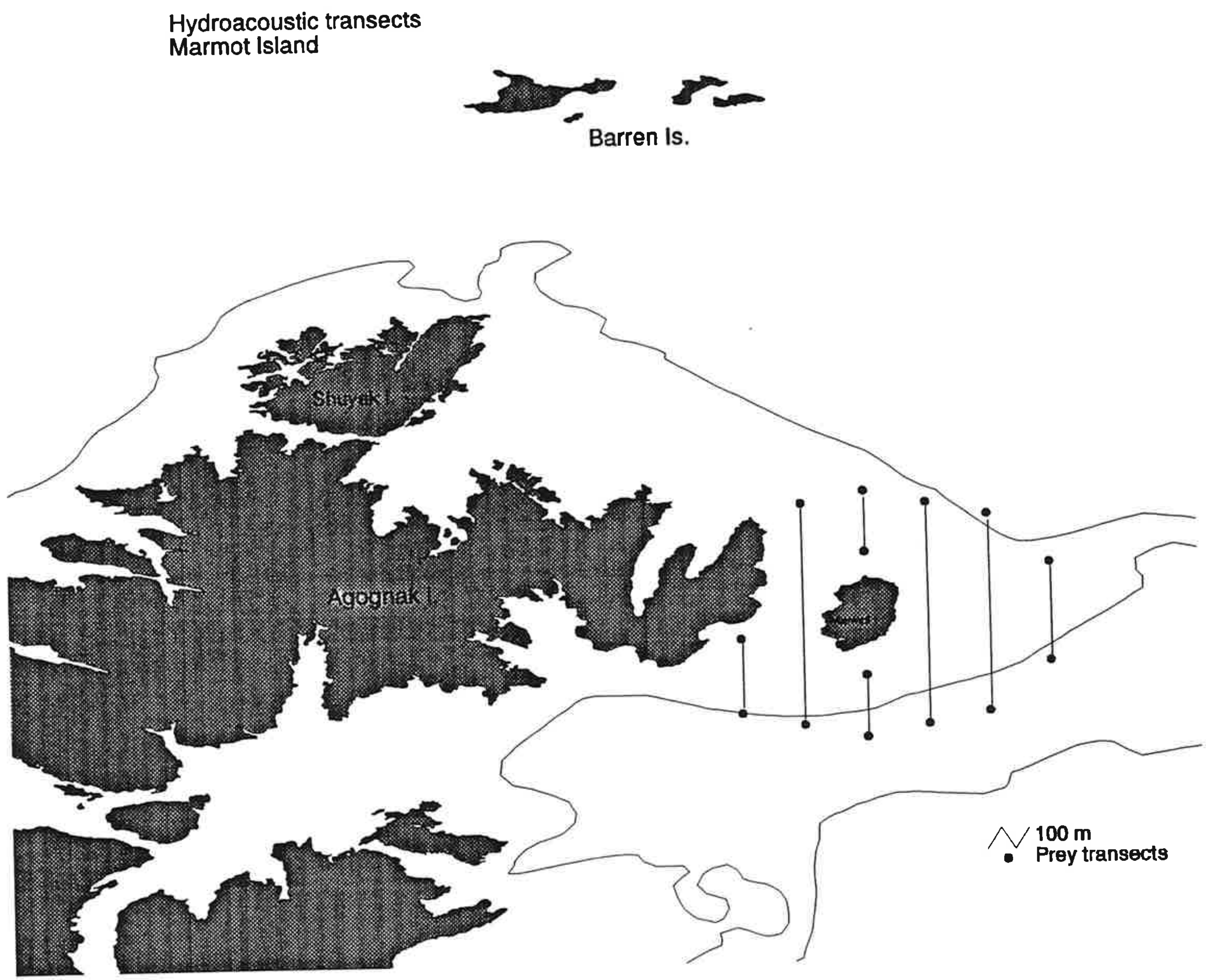

Figure 3. Hydroacoustic transects near Marmot Island, Alaska.

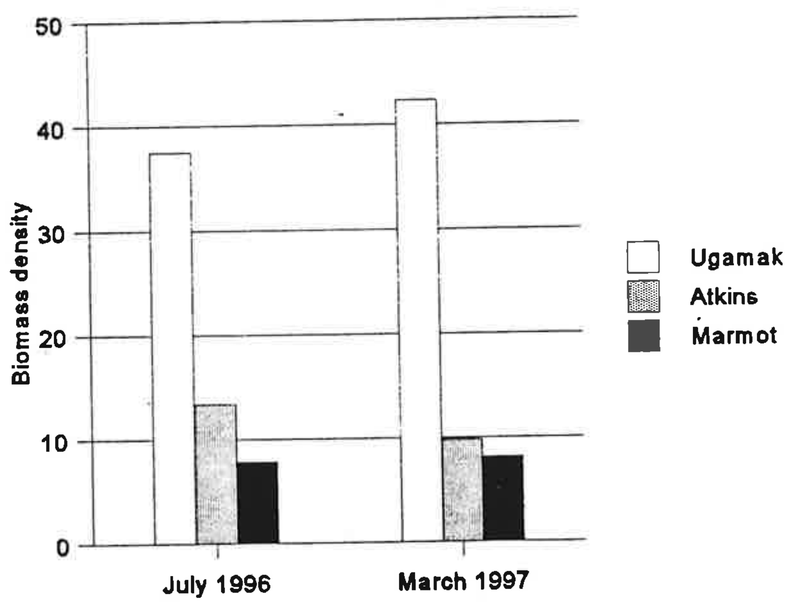

Figure 4. Hydroacoustically derived mean biomass density from surveys condicted at Ugamak, Atkins, and Marmot Islands during July 1996 and March 1997.

POPULATION ANALYSIS FOR ENDANGERED SPECIES

L. L. Eberhardt

2528 West Klamath
Kennewick, Washington, 99336

Abstract

The use of index data to determine whether a particular population is increasing is a common practice in wildlife management. However, this analysis indicated that in some cases such a practice can lead to misleading results. The basic approach used in this study was to compare estimates of trends in abundance from index data and from life history data. For example, using index of abundance information for Florida manatee's resulted in estimates of rates of change that were unrealistic, exceeding the limits of what would be feasible for a species with a life history similar to that of a manatee. Another aspect of this study was to test the validity of confidence limits for estimates of rate of change obtained from life history data. This was done via Monte Carlo simulations. The results were encouraging. The final aspect of the study was directed at assessing the utility of existing predator-prey models for marine mammal populations. In this case, it is likely that modeling predator-prey interactions for species with life histories similar to marine mammals will require the development of new models that only utilize parameters that can be typically estimated in the field.

Introduction

Understanding the dynamics of an endangered species sufficiently well to design a management program requires knowledge of reproductive and survival rates. However, it is often necessary to resort to indices of population trend in the initial stages of such a study. The present investigation has examined index data for three species for which the availability of reproductive and survival data makes it possible to obtain an independent estimate of the rate of population change. It is thus possible to directly check the validity of trend indices. Further understanding of the index data is available from several criteria that can be applied directly to the data, and were tested in the present study.

Results

Analysis of Index Data

An index to abundance of the Florida manatee had previously been developed by Garrott et al. (1994, 1995) based on multiple regression models (in the form of Cox's proportional hazards model) of the relation of aerial counts in warm-water refugia to a number of temperature measurements. Reanalysis of the data in the present study indicates that the annual rate of increase estimated from the regression models is unrealistic, exceeding that feasible for manatees. An alternative approach was developed in the present study in the form of pooled within-year regressions of logarithms of the counts on the major auxiliary temperature variable (covariance analysis). Adjusting yearly means of the logarithms of manatee counts with the pooled regression slope gave a trend that is in accord with the rate of change estimated directly from reproductive and survival data. The best indication from these analyses is that the manatee population had become roughly stable during the later period of the previous analyses.

In the case of the Yellowstone grizzly bear there are no repeated counts within years to provide the alternative check on a multiple regression model as was possible for manatees. However, the general upward trend of the population since the early 1980s indicated by a multiple regression model is confirmed by independent estimates from reproductive and survival rates. Additional support comes from behavior of several criteria (residual mean square, R^2, and Mallow's C_p), and the pattern of residuals from the final regression model. The new model developed in the present study increases the fraction of variability in the data accounted for by the model from 47% in the previously published model (Knight and Eberhardt 1985) to 71%. Further reassurance as to accuracy of the model comes from the agreement of the general population trend with recent overall understanding of progression of the Yellowstone grizzly population since the 1960s.

The Hawaiian monk seal data provide another view of the issues involved in using an index of abundance. Beach counts have been used to assess monk seal populations for over 40 years. The beach count data appear to be internally consistent in that variability within years is relatively small and mean counts do appear to agree generally with total counts. However, in the present study, more detailed analyses of the data on the site (Laysan Island) with the best estimates of total population size indicates that the beach counts are very poor guides to year-to-year trends. In this example, the availability of tags and other means of identification of individual monk seals has made it possible to obtain direct estimates of abundance by calculating the probability of sighting for each count, and thus population size. Estimates thus obtained in recent years (1990 through 1996) have very small standard errors, show little change from year to year, and are in accord with independent estimates of trend obtained from reproductive and survival data.

Overall, the analysis of index data in the present study indicates that index data can be misleading and thus somewhat risky to use, both as to general trend of a population and in assessing year-to-year changes. Nonetheless, the usual lack of sufficient resources and data often forces use of trend data. Detailed study of possible auxiliary variables in an effort to improve an index is thus very important, as demonstrated by the three examples developed in the present investigation. A draft manuscript reporting the results of this study has been prepared.

Assessment of the Validity of Confidence Limit Estimates

Another element of the study was devoted to a Monte Carlo assessment of the validity of confidence limits for estimates of the rate of population change obtained from reproductive and survival data. The basic equation (Lotka's equation) for estimating rate of change must be solved iteritively so no direct estimates of confidence limits are available. The statistical technique of bootstrapping provides a useful alternative but its validity for this purpose has not previously been demonstrated. A supplemental technique, the delta method, can be used to estimate proportions of the overall variance of an estimate due to separate components (early survival, adult survival, and reproductive rate). The Monte Carlo trials (1,000 independent simulations for each example) demonstrated that the bootstrap method provides accurate confidence limits (92 to 95% confidence limits actually included the true rate of change). Results from the delta method were very close to those from bootstrapping, so that the Monte Carlo work demonstrates the utility and validity of these two valuable techniques.

Assessment of Predator-prey Interaction Models

A third effort in the present study has been concerned with assessing the possible models for the predator-prey type of interaction. The research was directed towards evaluation of potential models that use actual data. Suitable field data did not appear to be available for endangered marine mammals, so data on predation of wolves on ungulates was used. The basic Lotka-Volterra predator-prey model was employed and successfully fitted to actual field data from a number of sources. One of the important findings of the study was that the models used in the current literature on predator-prey interactions were not suitable for large mammals (these models were almost entirely developed from data on invertebrates). Results of the study have been accepted for publication in a peer-reviewed journal (Eberhardt in press).

Citations

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